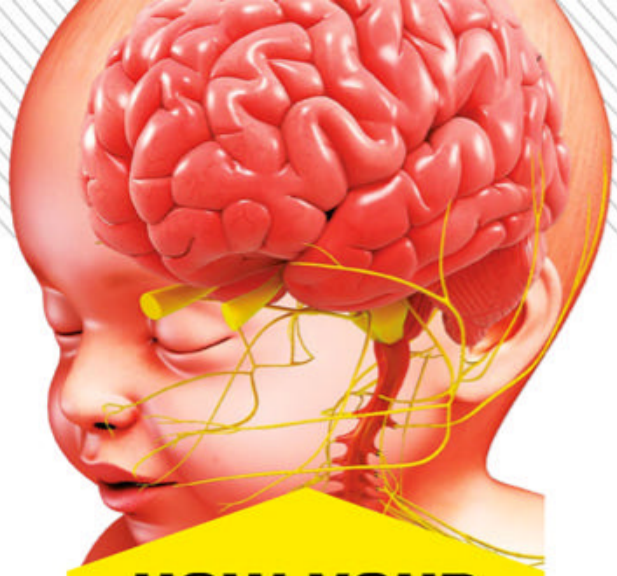


SPACE STATIONS
OF THE FUTURE

HOW IT WORKS



HOW YOUR
BRAIN
GROWS



WHAT
INSPIRED
**The Lord
of the
Rings?**



AMAZING WATER-SKATING
ELECTRIC BIKE



FRUIT OR VEGETABLE?
TEST YOUR KNOWLEDGE



HOW YOUR CLOTHES
ARE MADE

SUPERBUGS

HOW WE TREAT THE BACTERIA, VIRUSES, FUNGI
AND PARASITES THAT RESIST MEDICINE

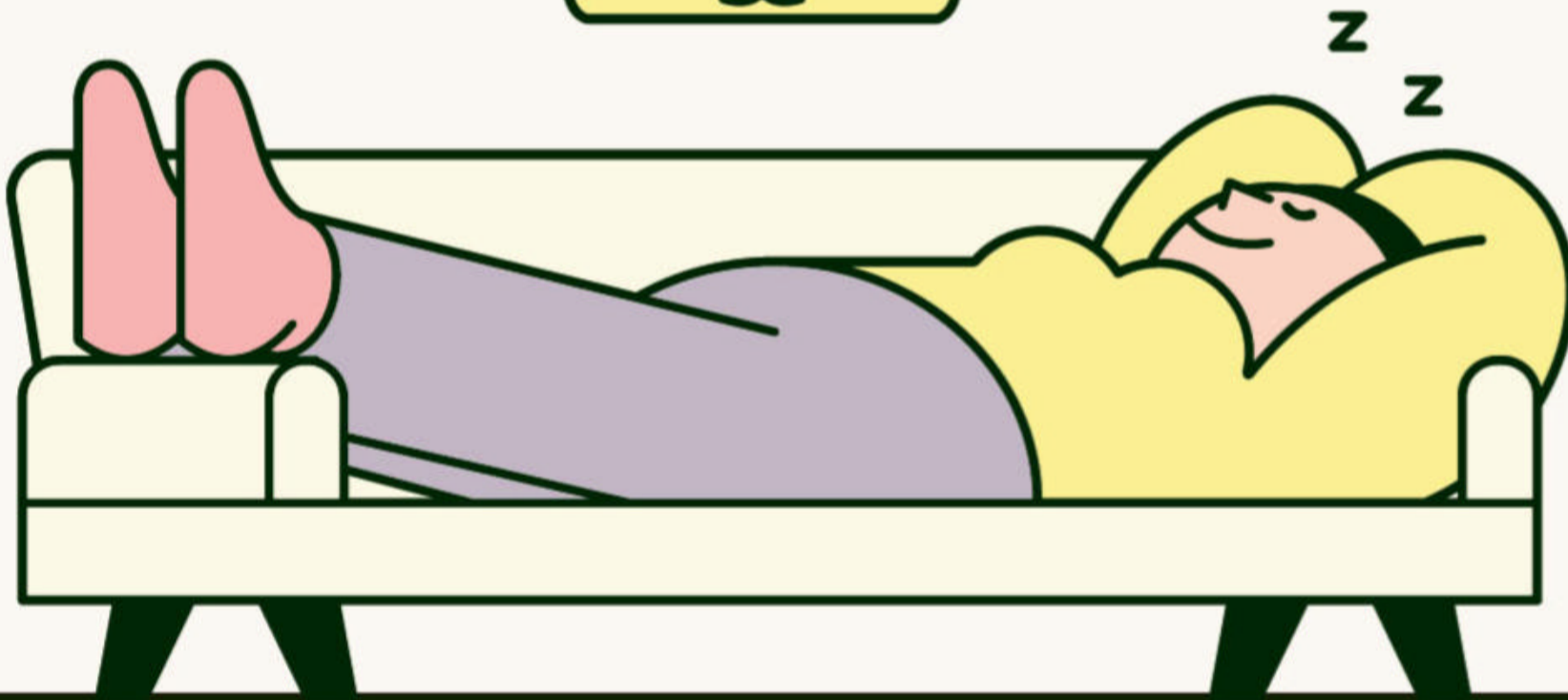


POMPEII'S
SECRETS
UNCOVERED

FUTURE
ISSUE 193

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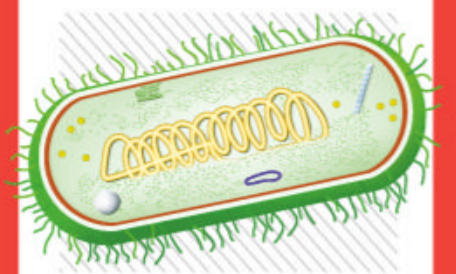
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NEWSLETTER



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“It’s expected that the first ‘AI antibiotics’ will emerge around 2030”



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GO TO PAGE 24 FOR GREAT DEALS



Antibiotics are one of the most important discoveries of the 20th century. In the war against disease and potentially deadly infections, they’re arguably the most effective treatment in medicine – or at least they were until bacteria and other bad bugs started fighting back against this panacea around 50 years ago. Today, figuring out a way to beat bacteria that are becoming increasingly resistant to all but our best antibiotics is a major headache for health experts, but all is not lost. This issue, we explain how pathogens have evolved to protect themselves against the drugs that would once have killed them, and the innovative ways in which we treat new and nasty strains of bacteria. Enjoy!



Ben Biggs
EDITOR

WHAT WE'RE ANTICIPATING



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PRODUCTION EDITOR



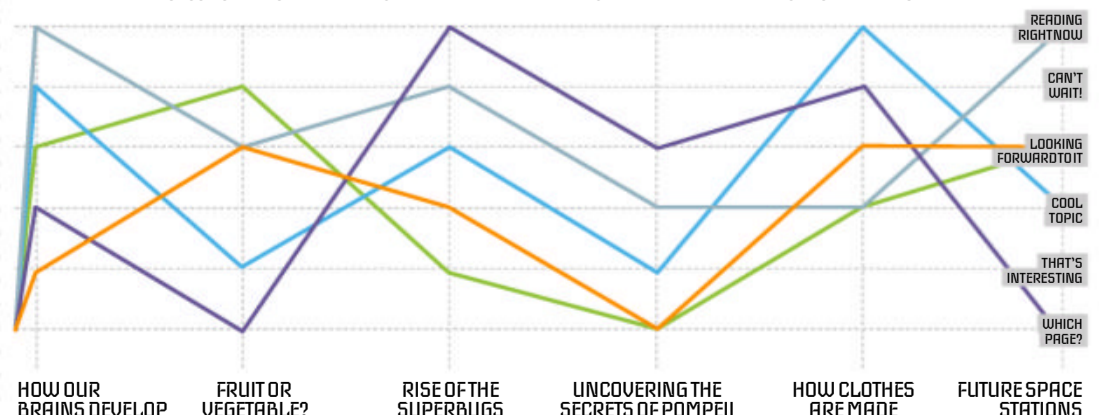
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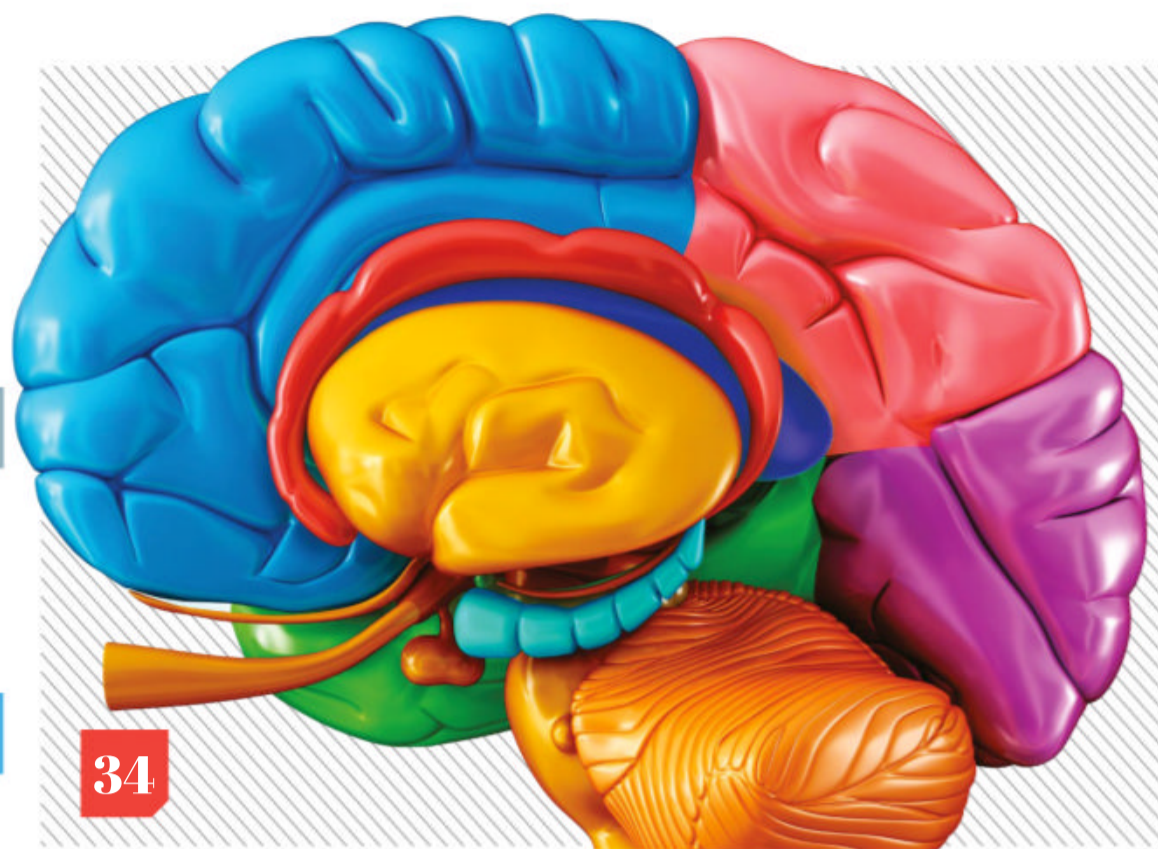
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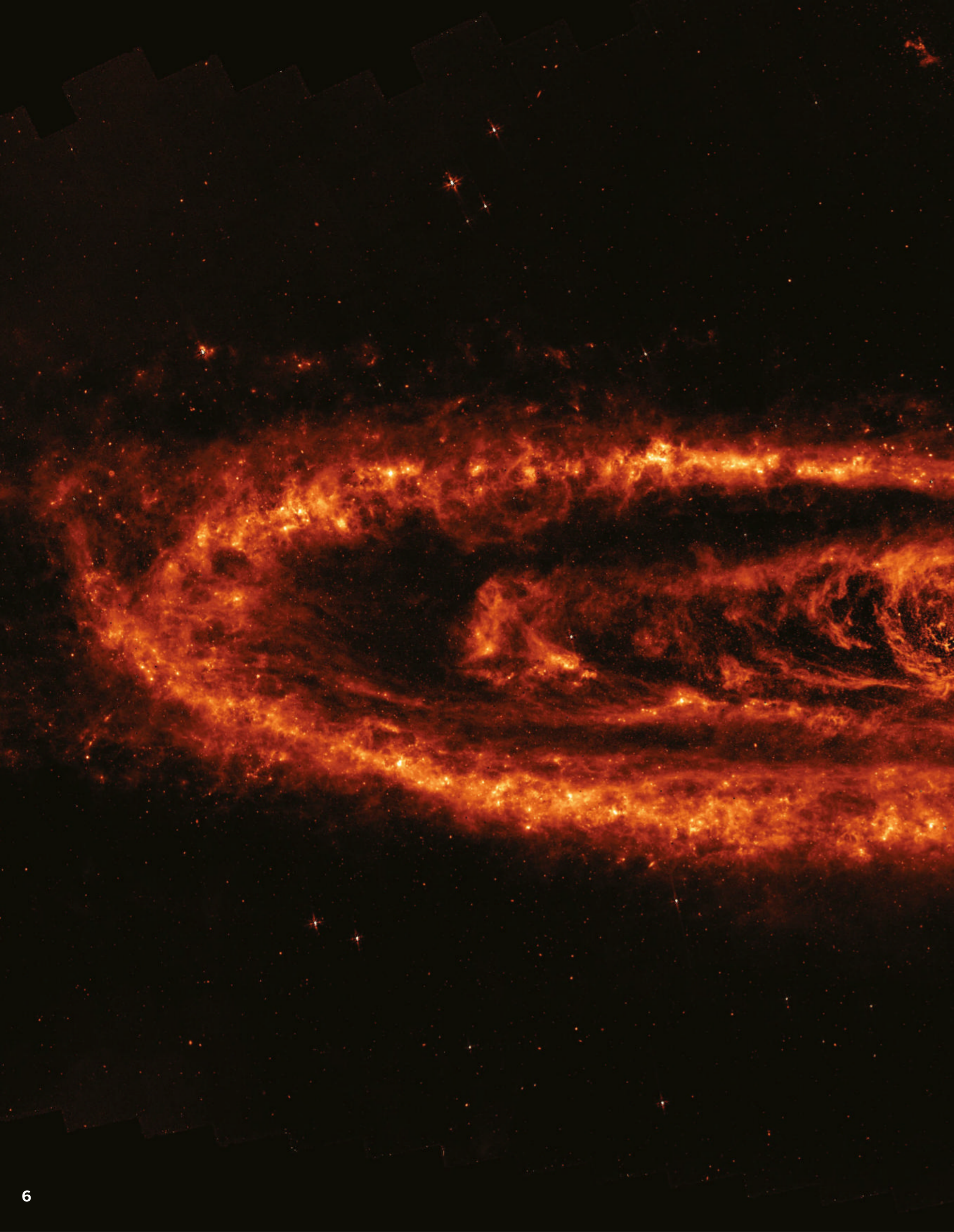


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Rings of cosmic fire

This image, snapped by NASA's Spitzer Space Telescope, shows the cosmic dust and gas of the Andromeda Galaxy. Lying a relatively short distance of 2.5 million light years away, our closest galactic neighbour is home to around a trillion stars, but it is cosmic dust and gas that dominate the galaxy. Spitzer captured the infrared light emitted by the galaxy to create this fiery view.







Caught in the rain

This bumblebee has fallen foul of a downpour while feasting on nectar. To protect itself from wet weather, a bee's body is coated with thick hairs. The hairs lock out water and retain vital body temperature. However, a shower may be too strong for a bee to fly in without running the risk of drowning, so they often stay put to wait out the rain and dry out.



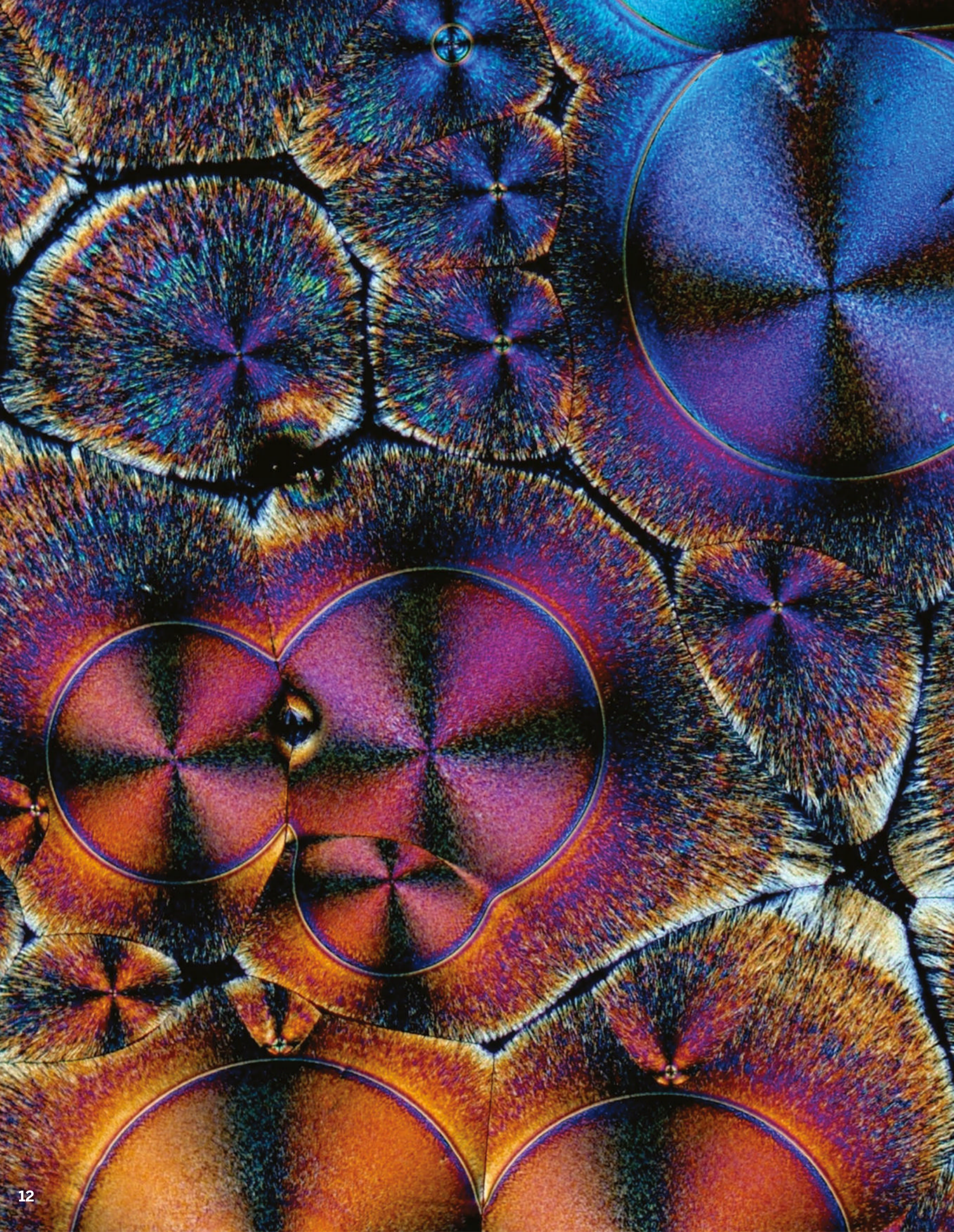




The dragon temple

Just outside the city of Bangkok, Thailand, is the breathtaking Wat Sam Phran Dragon Temple, seen here with the light of the setting Sun seemingly in its mouth. Built in 1985, this 17-storey temple features a mythical dragon that wraps around the building and houses the staircase to the top. In honour of Buddha, who died at the age of 80, the temple is 80 metres tall.







Vitamin C crystals

This is what vitamin C looks like when it's been diluted with alcohol and left to form crystals on a microscope slide. The result is mesmerising crystals that appear multicoloured under polarised light. When this light is passed through crystalline vitamin C, it's split and refracted in two directions – a phenomenon called birefringence. Birefringent materials can create colourful patterns.



GLOBAL EYE

Showcasing the incredible world we live in

The ITER tokamak pictured during its assembly in 2021



TECHNOLOGY

The world's largest nuclear fusion reactor is finally complete

WORDS BEN TURNER

The world's largest fusion reactor has finally been assembled, but project scientists have announced that it won't run for another 15 years. The International Thermonuclear Experimental Reactor (ITER), consisting of 19 massive coils looped into multiple toroidal magnets, was originally slated to begin its first full test in 2020. Now scientists say it will fire in 2039 at the earliest. This means that fusion power, of which ITER's tokamak is at the forefront, is very unlikely to arrive in time to be a solution for the climate crisis. "Certainly, the delay of ITER is not going in the right direction," said Pietro Barabaschi, ITER's director-general. "In terms of the impact of nuclear fusion on the problems humanity faces now, we should not wait for nuclear fusion to resolve them. This is not prudent."

The world's largest nuclear fusion reactor is the product of collaboration between 35 countries, including every state in the European Union, Russia, China, India and the US. ITER contains the world's most powerful magnet, making it capable of producing a

magnetic field 280,000 times as strong as the one shielding Earth. But the reactor's impressive design comes with an equally hefty price tag. Originally slated to cost around £4 million (\$5 billion) and fire up in 2020, it has now suffered multiple delays, and its budget has swelled beyond £17 million (\$22 billion), with an additional £4 million (\$5 billion) proposed to cover additional costs. These unforeseen expenses and delays are behind the 15-year delay.

Scientists have been trying to harness the power of nuclear fusion, the process by which stars burn, for more than 70 years. By fusing hydrogen atoms to make helium under extremely high pressures and temperatures, stars convert matter into light and heat, generating enormous amounts of energy without producing greenhouse gases or long-lasting radioactive waste. But replicating the conditions found inside stars is no simple task. The most common design for fusion reactors, the tokamak, works by superheating plasma before trapping it inside a doughnut-

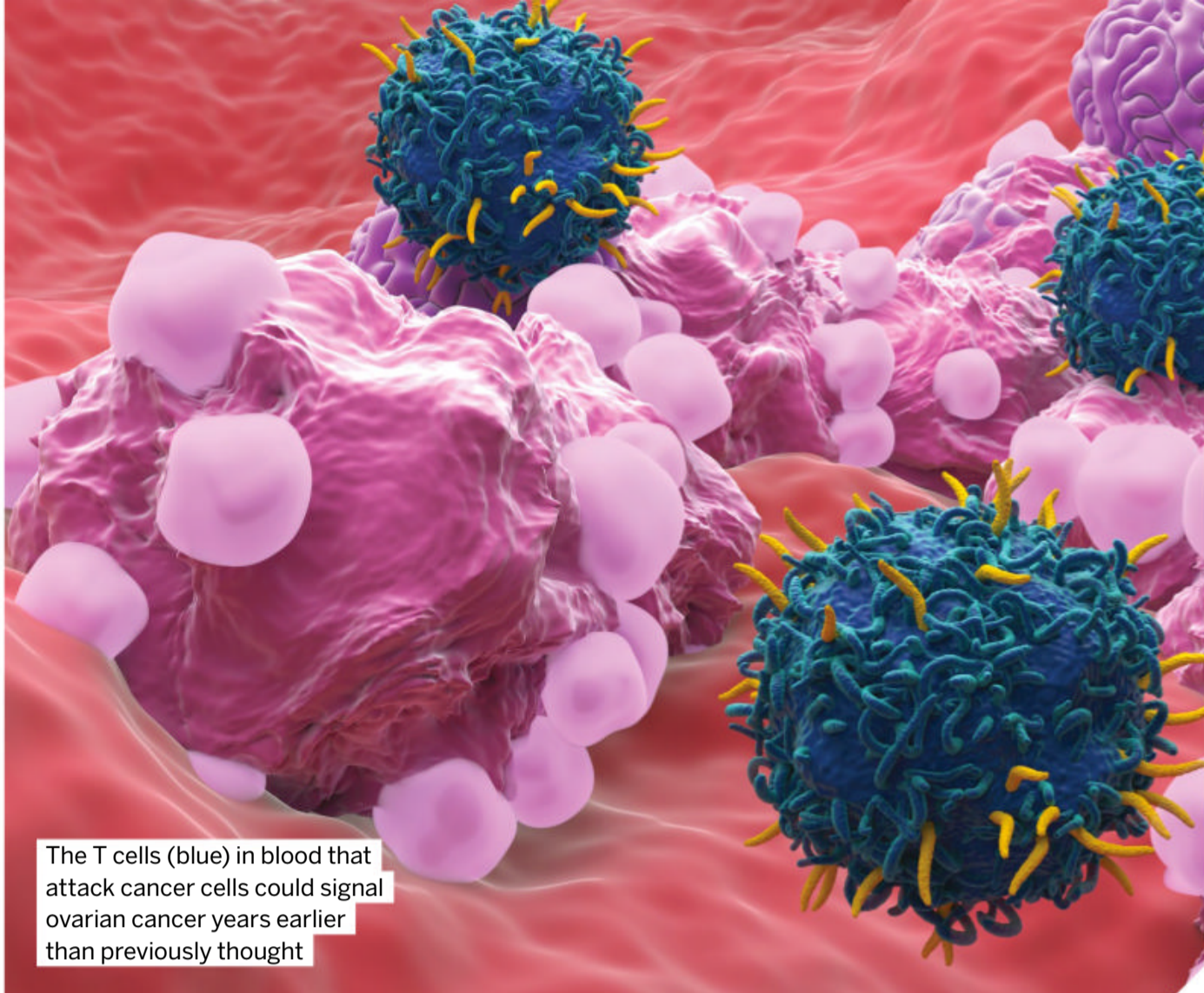
shaped reactor chamber with powerful magnetic fields. Keeping the turbulent and superheated coils of plasma in place long enough for nuclear fusion to happen, however, has been challenging.

Soviet scientist Natan Yavlinsky designed the first tokamak in 1958, but no one has since managed to create a reactor that is able to put out more energy than it takes in.

One of the main stumbling blocks is handling plasma that's hot enough to fuse. Fusion reactors require very high temperatures because they have to operate at much lower pressures than is found inside the cores of stars. The core of the actual Sun, for example, reaches temperatures of around 15 million degrees Celsius, but has pressures roughly equal to 340 billion times the air pressure at sea level on Earth. Cooking plasma to these temperatures is the relatively easy part, but finding a way to corral it so that it doesn't burn through the reactor or derail the fusion reaction is technically tricky. This is usually done either with lasers or magnetic fields.

Did you know?

The ITER tokamak weighs around 23,000 tonnes



The T cells (blue) in blood that attack cancer cells could signal ovarian cancer years earlier than previously thought

HEALTH

Blood tests detect ovarian cancer years before conventional methods

WORDS EMILY COOKE

Immune signatures in the blood may flag if someone has ovarian cancer up to four years earlier than conventional methods used to diagnose the disease. Ovarian cancer is one of the deadliest cancers, with a five-year survival rate of less than 51 per cent. Around 70 per cent of ovarian cancer patients have high-grade ovarian cancer (HGOC), in which cancerous cells look particularly abnormal and are more likely to grow and spread than low-grade cancers.

As with many cancers, early diagnosis and treatment, such as with surgery and chemotherapy, are key to longer survival. If this type of cancer is localised, that is, limited to the ovaries or the fallopian tubes, around 93 per cent of patients are expected to survive for five or more years after diagnosis. Unfortunately, most patients are not diagnosed with HGOC until the cancer is at an advanced stage, meaning it has spread to somewhere else in the body. In these cases, the five-year survival rate may be as low as 31 per cent.

One reason for this is that HGOC doesn't have specific symptoms in the early stages of the disease. During this time, tumours are very small, and conventional biomarkers, such as the CA-125 blood test that detects raised levels of a cancer-related protein, are not sensitive enough to detect them. However, a new study may help doctors diagnose ovarian cancer much sooner, allowing for earlier treatment

before the cancer has spread, and potentially longer survival.

Researchers discovered a blood-based immune biomarker that they say could be used to detect HGOC up to four years before most cases are currently diagnosed. They uncovered this biomarker after analysing blood samples taken from 466 patients who went on to be diagnosed with ovarian cancer using conventional clinical tests. Specifically, the team noticed strong differences in the numbers of immune cells called T cells in their blood that were primed to recognise and attack cancer cells compared with those found within the blood of a comparison group of women who did not go on to develop cancer.

This discovery could one day inform the development of new tests that detect this biomarker. "Early detection of ovarian cancer could mean the difference between life and death for millions of women," said Bo Li, a researcher at the Children's Hospital of Philadelphia's Center for Computational and Genomic Medicine. "We believe our findings can be a game changer, providing insights for the development of an immune-based biomarker to detect early-stage ovarian cancers."

ARCHAEOLOGY

NAILED ROMAN MILITARY SANDAL FOUND IN GERMANY

WORDS JENNIFER NALEWICKI

Archaeologists have discovered the remains of a 2,000-year-old Roman sandal near an ancient military fort in Germany. Researchers unearthed the footwear while conducting excavation work at a civilian settlement on the outskirts of a Roman military fort near Oberstimm, which would have been occupied sometime between 60 and 130 CE. All that was left of the leather shoe, which researchers analysed using X-rays, was its sole and some well-preserved nails.

X-rays revealed that the shoe was a caliga, a heavy-duty, hobnailed sandal that was part of the uniform issued to Roman legionary soldiers and auxiliaries. The shoe would have been worn while the person was marching, with the nails providing traction. Caligae were protective against blisters and conditions such as trench foot.

However, the Roman army began transitioning away from wearing these sandals by the end of the 1st century CE. At that point, Roman soldiers tended to wear enclosed boots known as calcei. "So-called caligae were mainly worn by Roman soldiers during the Roman Empire," said Amira Adaileh, a consultant at the Bavarian State Office for Monument Preservation. "The find makes it clear that the practices, lifestyles and clothing that the Romans brought with them to Bavaria were adopted by the local people."

A recreation of what the Roman sandal may have looked like





The snaking scar that runs along Mars' surface

SPACE

Mars orbiter spots a Martian scar longer than the Grand Canyon

WORDS VICTORIA CORLESS

New images published by the European Space Agency have captured a 373-mile-long snaking scar on Mars' surface in greater detail than ever before. The Red Planet is full of scratches and scars, and this one, named Aganippe Fossa, is another of these ditch-like grooves with steep walls. More specifically, Aganippe Fossa is what's called a 'graben'. "We're still unsure of how and when Aganippe Fossa came to be, but it seems likely that it was formed as magma rising underneath the colossal mass of the Tharsis volcanoes caused Mars' crust to stretch and crack," ESA officials wrote in a statement.

As is common in planetary nomenclature, the name 'Aganippe Fossa' has its roots in classical mythology. Aganippe, daughter of the river Termessos, was a nymph associated with a spring found at the base of Mount Helicon in Greece. In homage to its naming origins, Aganippe Fossa appears at the base of one of Mars' largest volcanoes, Arsia Mons. 'Fossa' is then derived from the Latin term for ditch or trench, and refers to a long, narrow depression on the surface of a planet or moon.

The recent images owe themselves to the ESA's Mars Express, Europe's first mission to the Red Planet, which has been orbiting Mars since 2003. Although its lander, Beagle 2, was lost, the orbiter is still conducting a global investigation of Mars. It maps minerals, studies the atmosphere, probes beneath the crust and investigates the planet's blob-shaped moons, Phobos and Deimos. Mars Express captured the new images of Aganippe Fossa with its

high-resolution stereo camera and revealed the varied surface features of Mars in great detail, showing both clustered, uneven hills and smooth, gently sloping cliffs covered in debris, referred to as hummocky and lobate terrains respectively.

These terrains are characteristic of Arsia Mons' ring-shaped 'aureole,' in reference to a 38,610-square-mile disc around the base of the volcano, possibly associated with ancient glaciers. "Intriguingly, this aureole has only built up on the northwestern flank of the volcano, likely due to prevailing winds from the opposite direction controlling where ice settled over time," ESA officials wrote. The team also describes windblown dust and sand dynamics of this region of Mars, which create 'zebra-like' patterns on the planet's surface as a result of darker material getting deposited on lighter ground. "The surface here also shows evidence of lava flows, dating from when the volcano was active."

Aganippe Fossa is one of many classical albedo features on Mars, which refers to the light and dark features that can be seen on the planet through even an Earth-based telescope. With space-based orbiters, astronomers have been given unprecedented views of the planet's surface and its intriguing topography.

"Mars Express captured the new images of Aganippe Fossa"

ARCHAEOLOGY

2,500-YEAR-OLD SLATE WITH DRAWINGS OF BATTLE SCENES DISCOVERED

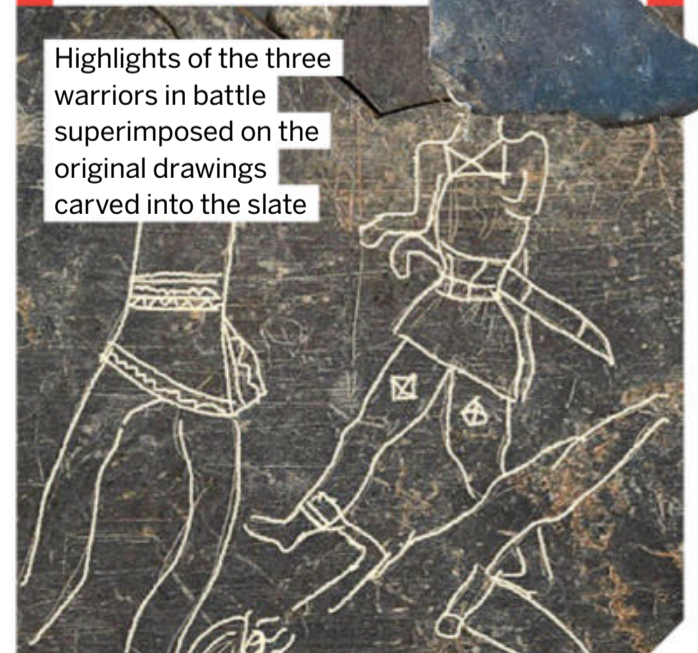
WORDS JENNIFER NALEWICKI

Archaeologists in Spain have discovered a unique tablet containing ancient drawings that depict battle scenes and an alphabet. The artworks were found during excavations at Casas del Turuñuelo, an ancient Tartessian site in southwestern Spain. The Tartessos people were an ancient civilisation that first settled in the Iberian peninsula around the 8th century BC and were known for their elaborate writing system. By the 4th century BC, they had vanished.

On the slate's perimeter, someone had carved an alphabetical sequence of 21 signs in Paleo-Hispanic script. Unfortunately, a piece of the slate was broken off, so researchers can only speculate as to which letters are missing. The plaque, which measures nearly 20 centimetres long, also contains engravings depicting three warriors in battle. Researchers think that the sketches were likely part of a drawing exercise the artist used to fine-tune their craft before carving similar motifs into pieces of gold, ivory or wood.



Highlights of the three warriors in battle superimposed on the original drawings carved into the slate



The secret to lifelong memories sticking is molecular 'glue'

WORDS EMILY COOKE

Some memories last a lifetime, and scientists have revealed a type of molecular 'glue' that helps those memories stick around. Memories form when collections of neurons in a region of the brain called the hippocampus activate in response to a particular experience. Each time you recall that experience, the same set of cells activates. When one neuron repeatedly activates another, the connection between those neurons strengthens. Over time, this process in the hippocampus, along with related activity in other regions of the brain, solidifies a short-term memory into a long-term one. To maintain these long-term memories, brain cells make proteins that help strengthen the connections, or synapses, between neurons. One critical protein is the enzyme PKMzeta, which is continually made by neurons. However, an outstanding question is how this enzyme 'knows' to go to the right synapses to ensure that certain memories stay with us forever.

Scientists think they've found the answer: an unsung molecule called KIBRA glues the enzyme to strong synapses and also summons new PKMzeta to replace that enzyme when it degrades. Previous research in humans suggested that different versions of the KIBRA molecule are associated with differences in memory performance, either better or worse. KIBRA was also already known to interact with the PKMzeta enzyme in the hippocampus of mice. The scientists behind a new study decided to delve further into that interaction. In lab experiments, the team investigated whether blocking the interaction between KIBRA and PKMzeta influenced how well mice performed in long-term memory tests. These tests included seeing whether the mice could remember to avoid entering an area where they had previously been shocked with electricity. Blocking the interaction between KIBRA and PKMzeta impaired the mice's long-term spatial memory – in other words, their ability to avoid the shock zone. In a separate experiment, when the KIBRA-PKMzeta interaction was left undisturbed, the team found that even when PKMzeta degraded as expected, new complexes of KIBRA and PKMzeta formed in the hippocampus. This in turn helped maintain the mice's memory of the shock zone for a month.

Earlier work by the same team showed that if researchers increase the amount of PKMzeta in a rodent's brain, it appears to enhance weak long-term memories that have faded over time. This initially surprised the scientists, as the team expected PKMzeta to boost the strength of synapses at random, rather than specifically acting on those involved in long-term memory. Instead, the new findings suggest that KIBRA acts like a 'glue,' sticking to these strong synapses and also guiding PKMzeta to them, which would explain this phenomenon.

The research is only in its infancy. However, eventually, it may be possible to use this knowledge to treat brain disorders that cause memory loss. For now, more research is needed to understand how the interaction between PKMzeta and KIBRA actually translates into people's experiences of memory.

Did you know?

There are around 100 trillion synaptic connections in the brain



Neuron connections, like the one illustrated here, are strengthened by protein 'glue'

SPACE

NASA'S FIRST YEAR-LONG MOCK MARS MISSION ENDS

WORDS MIKE WALL

The first mission in the Crew Health and Performance Exploration Analog (CHAPEA) series began on 25 June 2023, when four volunteers were sealed inside a simulated Mars habitat at NASA's Johnson Space Center in Houston. The quartet exited the habitat on 6 July 2024, returning to regular Earth life after a staggering 378 days. The four volunteers for the CHAPEA-1 mission were Kelly Haston, Anca Selariu, Ross Brockwell and Nathan Jones. Their home for just over a year was Mars Dune Alpha, a 158-square-metre 3D-printed habitat designed to feel like an isolated Red Planet outpost.

The quartet's experiences in Mars Dune Alpha will inform NASA's planning for real-life crewed missions to the Red Planet, which the agency aims to start launching in the late 2030s or early 2040s. "For more than a year, the crew simulated Mars mission operations, including 'Marswalks', grew and harvested several vegetables to supplement their shelf-stable food, maintained their equipment and habitat and operated under additional stressors a Mars crew will experience, including communication delays with Earth, resource limitations and isolation," said NASA officials.



Kelly Haston, commander of CHAPEA-1, just after she and her three crewmates exited the Mars Dune Alpha habitat



A new study shows the sign of climate breakdown are already here

PLANET EARTH

Earth exceeded the 1.5-degree-Celsius warming every month for entire year

WORDS BEN TURNER

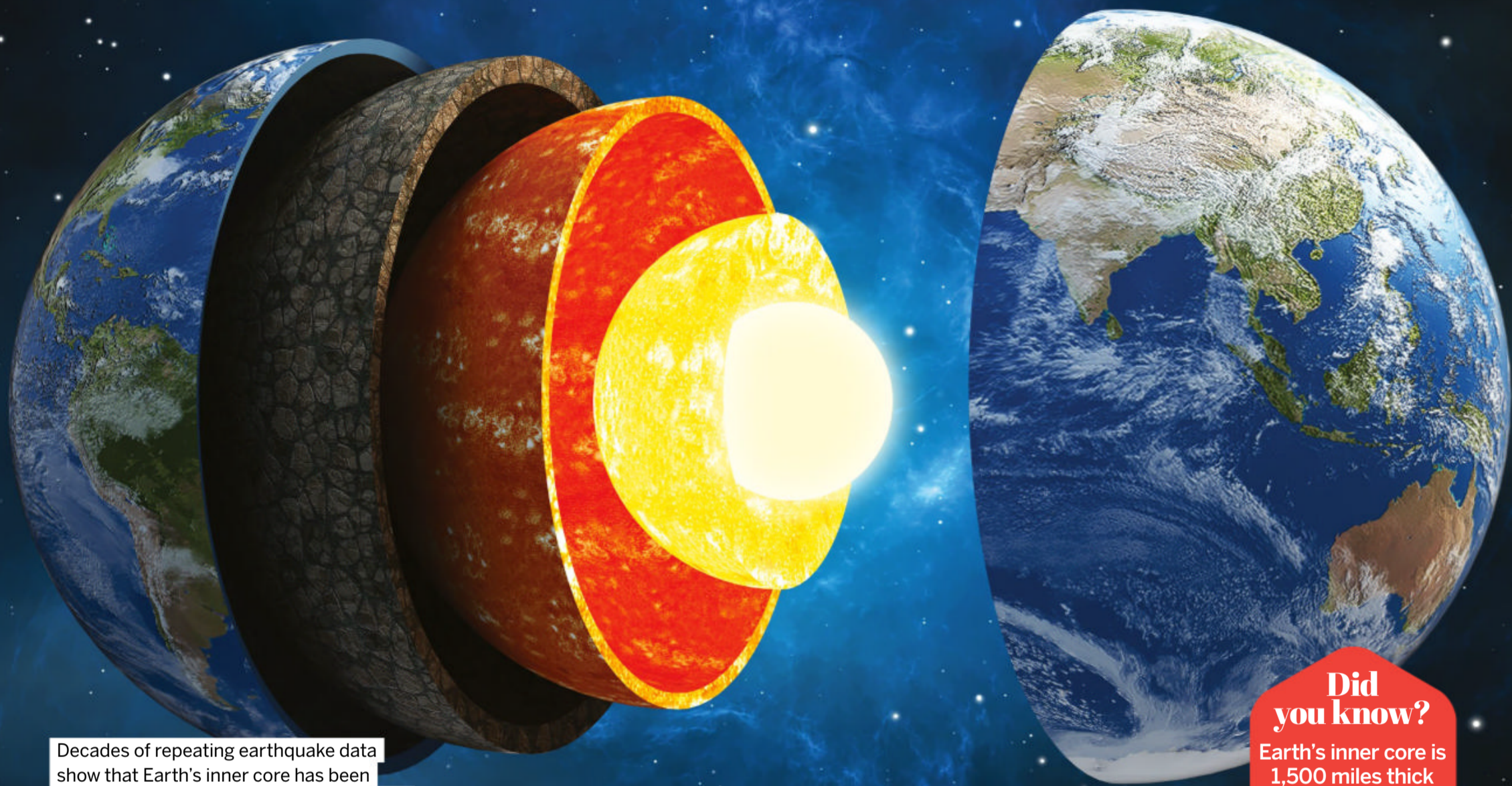
Earth has broken temperature records for 13 consecutive months, with every month registering temperatures 1.5 degrees Celsius higher than pre-industrial averages, according to a new report by the Copernicus Climate Change Service (C3S). Every month since June 2023 has been hotter than the one preceding it, making the global average temperature between July 2023 and June 2024 1.64 degrees Celsius greater than it was before the Industrial Revolution, when humans started burning fossil fuels to release huge quantities of greenhouse gases into the atmosphere. "This is more than a statistical oddity, and it highlights a large and continuing shift in our climate. Even if this specific streak of extremes ends at some point, we are bound to see new records being broken as the climate continues to warm," said Carlo Buontempo, director of the C3S. "This is inevitable unless we stop adding [greenhouse gases] into the atmosphere and the oceans."

The 12-month streak was in part driven by El Niño, a climate cycle where waters in the tropical eastern Pacific Ocean grow warmer than usual, which persisted from June 2023 to May 2024, leading to above-average sea temperatures across the east and central equatorial Pacific. "The climate continues to alarm us – the last 12 months have broken records like never before, caused primarily by our greenhouse gas emissions and an added boost from the El Niño event in the tropical

Pacific," said Samantha Burgess, deputy director of C3S.

Scientists consider global warming of two degrees Celsius above pre-Industrial Revolution temperatures an important threshold, as warming beyond this greatly increases the likelihood of devastating and irreversible climate breakdown. But 1.5 degrees Celsius is also an important limit. With rises of 1.5 degrees Celsius, the world's climate edges closer to multiple tipping points that will unleash heat waves, floods, famine and the widespread destruction of ecosystems, the United Nations warned in a 2018 special report. Under the 2015 Paris Agreement, nearly 200 countries pledged to limit global temperature rises to 1.5 degrees Celsius and safely below two degrees Celsius.

While the new findings are troubling, the report stresses that the 1.5 and two degrees Celsius limits are targets for the planet over a 20 to 30-year period, meaning the pledges haven't been broken just yet. But the record-high temperatures are unlikely to fall anytime soon. Scientists initially hoped that the end of El Niño might offer the planet a reprieve, but the US is still projected to have warmer-than-average temperatures for the rest of summer. "I now estimate that there is an approximately 95 per cent chance that 2024 beats 2023 to be the warmest year since global surface temperature records began in the mid-1800s," Zeke Hausfather, a climate scientist at the US non-profit Berkeley Earth, said.



Decades of repeating earthquake data show that Earth's inner core has been rotating more slowly over the last 14 years

Did you know?
Earth's inner core is 1,500 miles thick

PLANET EARTH

Earth's rotating inner core is slowing down

WORDS HARRY BAKER

The heart of our planet has been spinning unusually slowly for the past 14 years. And if this mysterious trend continues, it could potentially lengthen Earth's days, though the effects would likely be imperceptible to us. Earth's inner core is a roughly Moon-sized chunk of solid iron and nickel that lies more than 3,000 miles below our feet. It is surrounded by the outer core, a superhot layer of molten metals similar to those in the inner core, which is surrounded by a more solid sea of molten rock known as the mantle, and the crust. Although the entire planet rotates, the inner core can spin at a slightly different speed as the mantle and crust due to the viscosity of the outer core.

Since scientists started mapping Earth's inner layers with detailed seismic activity records around 40 years ago, the inner core has rotated slightly faster than the mantle and the crust. But researchers found that since 2010 the inner core has been slowing down and is now rotating a bit more slowly than our planet's outer layers. "When I first saw the seismograms that hinted at this

change, I was stumped," said John Vidale, a seismologist at the University of Southern California. "But when we found two dozen more observations signalling the same pattern, the result was inescapable."

If the inner core's rotation continues to decelerate, its gravitational pull could eventually cause the outer layers of our planet to spin a little more slowly, altering the length of our days. However, any potential change would be on the order of thousandths of a second, which would be "very hard to notice," Vidale said. As a result, we would likely not have to change our clocks or calendars to adjust for this difference, especially if it were only a temporary change.

This isn't the first time scientists have suggested that Earth's inner core is slowing down. This phenomenon, known as 'backtracking', has been debated for around a decade, but has been very hard to prove. Researchers analysed data from more than

100 repeating earthquakes, seismic events that occur repeatedly at the same location, along a tectonic plate boundary in the South Sandwich Islands in the South Atlantic Ocean between 1991 and 2023. Each earthquake allowed scientists to map the core's position relative to the mantle. By comparing these measurements, the team was able to see how

the inner core's rotation rate changed over time. It's the "most convincing" evidence so far that backtracking has been happening, Vidale said.

It is currently unclear why the inner core is backtracking, but it is likely

caused by either "the churning of the liquid iron outer core that surrounds it" or "gravitational tugs from the dense regions of the overlying rocky mantle." It's also unclear how frequent backtracking is. It's possible that the inner core's spin is constantly accelerating and decelerating, but these changes likely happen over decades or longer. Longer datasets are needed to infer anything about long-term trends.

"Earth's inner core is a chunk of solid iron and nickel"

This moss can withstand deadly blasts of radiation and extreme cold

PLANET EARTH

A near-indestructible moss can survive gamma rays

WORDS STEPHANIE PAPPAS

A frilly little desert moss can survive freezing conditions, dehydration and enough radiation to kill a human 1,000 times over. This moss, named *Syntrichia caninervis*, lives in harsh environments across the planet, from the Mojave Desert to Antarctica. Now, scientists have discovered that it could survive in even nastier conditions. When subjected to a week in an environment like the surface of Mars, the researchers found that the hardy moss could bounce back.

Its survival abilities may even outdo those of tardigrades, microscopic 'water bears' that can live in the vacuum of space. The moss is better at handling heat, and can survive even higher doses of radiation than tardigrades, researchers discovered after subjecting the moss to multiple ought-to-be-fatal indignities. "Our study shows that the environmental resilience of *S. caninervis* is superior to some of [the] highly stress-tolerant microorganisms and tardigrades," said Daoyuan Zhang, Yuanming Zhang and

Tingyun Kuang of the Chinese Academy of Sciences (CAS).

The team collected the moss from the Gurbantüggüt Desert in northern China. They first subjected samples of the moss to near-complete air-drying. Though the dried moss shrivelled and turned black, it returned to full springy greenness within 20 seconds of rehydration. After 99 per cent dehydration followed by rehydration, the moss returned to full photosynthetic capacity within two minutes. The moss also showed remarkable resilience against the cold. After 30 days of immersion in liquid nitrogen at -196 degrees Celsius, the moss could recover and grow new branches. It could also survive for at least five years at -80 degrees Celsius. While the moss rebounded fastest if it was dehydrated before freezing, it could also survive these conditions if frozen without being dried first.

Finally, the researchers zapped the moss with massive amounts of gamma radiation. They found that the moss could survive up to 4,000 gray of ionising radiation without much

trouble. For comparison, four gray is considered a fatal dose of ionising radiation for humans. A dose of ionising radiation is considered fatal when it kills half of those exposed to it. For *S. caninervis*, the fatal dose is 5,000 gray. Even the hardy tardigrade tops out at 4,200 gray.

The moss can also handle hits from multiple stressors at once. The researchers put moss samples in the CAS Planetary Atmospheres Simulation Facility, which mimics the atmosphere of Mars in surface pressure, temperature, gas make-up and radiation. After seven days in this environment of mostly carbon dioxide, with temperature swings ranging from -60 degrees Celsius to 20 degrees Celsius and hazardous levels of radiation, the moss still bounced back, recovering and growing new branches after 15 days back in Earth-like conditions. The findings suggest that the moss could be used in attempts to terraform Mars by introducing plants that can survive its harsh environment and create a more Earth-like surface and atmosphere.

Florida carpenter ants perform amputations on nestmates when their legs are injured



ANIMALS

Florida ants perform life-saving operations on other ants

WORDS JACKLIN KWAN

Ants in Florida perform life-saving surgery on their peers, scientists have discovered. They are only the second animal in the world known to do this, along with humans. The researchers found that Florida carpenter ants identify limb wounds on their nestmates, then treat them with either cleaning or amputation. “When we’re talking about amputation behaviour, this is literally the only case in which a sophisticated and systematic amputation of an individual by another member of its species occurs in the animal kingdom,” said Dr Erik Frank, a behavioural ecologist at the University of Würzburg in Germany.

In 2023, Frank’s team discovered that an African ant species, *Megaponera analis*, can treat infected wounds in their nestmates with an antimicrobial substance produced in their glands. Florida carpenter ants do not have any equivalent glands, so the team wanted to find out how this species handles wounds in members of the colony. Specifically, scientists looked at two types of leg wounds: lacerations on the femur and those lower down on the tibia. In experiments, they observed that the ants treated their nest members’ femur injuries by cleaning the wound with their mouths before amputating the leg by repeatedly biting it, while the tibia wounds were treated with just cleaning.

Did you know?

There are around 8,000 carpenter ants in a colony

The surgeries resulted in significant improvements in the survival of their patients. Survival rates for femur injuries improved from less than 40 per cent to between 90 and 95 per cent when amputations were performed, while survival rates for tibia injuries improved from 15 to 75 per cent following cleaning. The scientists suggest ants only amputate femur injuries, rather than all leg injuries, because of speed limitations. An amputation takes ants at least 40 minutes to complete. After studying the ants, the researchers speculated that the damage to blood-pumping muscles in the femur causes blood circulation to slow. This would mean that bacteria-laden blood would take longer to enter the body, allowing the ants enough time to amputate the limb.

Ant tibias, meanwhile, have relatively little muscle tissue, so infections can spread faster. This means amputation would take too long for the ants to stop the spread of harmful bacteria, so they instead focus on cleaning the wound. “The ants are able to diagnose a wound, see if it’s infected or sterile and treat it accordingly over long periods of time by other individuals – the only medical system that can rival that would be the human one,” Frank said. The scientists are now extending their research to other ant species that don’t possess special antimicrobial glands to see if other ants have the ability to perform surgeries.

SPACE

LEGO ‘SPACE BRICKS’ COULD INSPIRE LUNAR HABITATS

WORDS RAHUL RAO

Scientists from the European Space Agency (ESA) have begun toying with a very interesting idea: fashioning space dust into LEGO-like bricks and building with them. “Nobody has built a structure on the Moon, so it was great to have the flexibility to try out all kinds of designs and building techniques with our space bricks,” said the ESA’s Aidan Cowley.

But there’s a slight catch. The ESA’s space bricks aren’t actually fashioned from moon dust. For all the lunar samples that various missions have returned to Earth, lunar regolith is simply too scarce and scientifically valuable to use for bricks. Instead, ESA scientists turned to a simulant: regolith from a meteorite. Specifically, scientists used 4.5-billion-year-old material from a meteorite discovered in Northwest Africa around the year 2000. Using a 3D printer, they fashioned the meteorite dust into bricks shaped like classic two by four LEGO bricks.

The resultant bricks are not entirely like LEGO – they are significantly rougher, for one – but they’re recognisable enough. They can stack just like LEGO can, and builders can assemble them into different structures. They’re similarly exciting to play with, but also able to help scientists test construction methods and determine which ones might work best with the material at hand.

European Space Agency scientists are using LEGO-inspired ‘space bricks’ to design lunar habitats



WISH LIST

The latest **BOARD GAMES**

TERRAFORMING MARS

£47.99 / \$79.99 FRYXGAMES.SE

People are looking for a new home on Mars, but need you to transform its barren landscape into a habitable world. In Terraforming Mars, you'll play as one of the corporations working to create a breathable atmosphere, oceans of water and raise the temperature to sustain human life on the Red Planet. From over 200 different project cards, players will buy their way to build up the production of resources and meet different milestones to ultimately gain the highest terraforming rating and win the game. This is a great world-building game to sink your teeth into for up to five players.



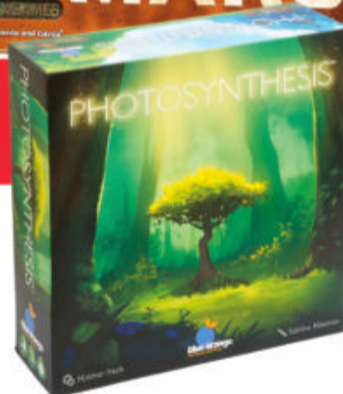
PHOTOSYNTHESIS

£39.99 / \$47.95

BLUEORANGEGAMES.COM

From seedling to full spruce, players of Photosynthesis follow trees through the circle of life and craft forests on the game board. As the Sun moves around the board, your trees will collect energy points for you to spend growing more trees. However, players can

thwart the forests of their competition by planting competing trees to block their access to light and limit the energy points that they can yield. Up to four players can put their forestry skills to the test in this vibrantly illustrated strategy game.



SCYTHE

£91 / \$99 STONEMAIERGAMES.COM

Set in an alternate history of the 1920s, Scythe lets players traverse a war-torn landscape to rebuild their factions' resources. A game for up to five players, each represents a fallen leader, and it's your job to conquer territories, enlist recruits and build structures to grow your faction and restore your honour. Players can upgrade aspects of their campaign on the board, including building structures, enhanced character abilities and weaponry. Each player is also given a hidden objective to complete to gain extra resources on their path to claim victory.



EVOLUTION

£36 / \$44.99

NORTHSTARGAMES.COM

Evolution is a creative card game that lets players hold evolution in their hands. With more than 12,000 different trait combinations to explore, players will have to adapt their species to contest with a constantly changing ecosystem. They can also evolve into predators or prey to exploit resources in their environment. Over time, species' populations will grow until they can't handle the hostile environments or fend off predators and become extinct. The player with the best adapted species will win the game.



TURING MACHINE

£36 / \$39.99 SCORPIONMASQUE.COM

Inspired by the great analytical mind of Alan Turing, Turing Machine is a competitive deduction game that requires you to be the first to crack the secret code. Through a series of clue cards and a punch-card analogue computer, players attempt to solve one of the many problems in rounds until one or more of them get the right combination of numbers and solves the code. Plus, the game doesn't have to end after all the problems in the physical game are complete because there are more than 7 million extra problems available online at turingmachine.info.

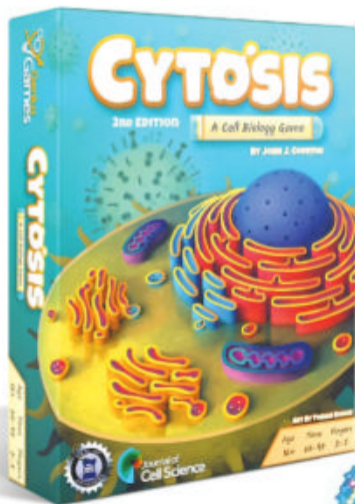


CYTOSIS

£39 / \$44.99

GENIUSGAMES.ORG

If you've ever wondered what it's like to keep a human cell functioning, Cytosis has you covered. This cell biology board game requires players to gather resources such as carbohydrates and complete actions to keep the cell ticking over and collect health points. From building enzymes to detoxifying a cell, there are a lot of different ways to gain points and resources. The player with the most health points by the end of the game wins. Along with being a fun and competitive board game, players will also learn the roles of some of the most important organelles in the human cell, such as mitochondria and the Golgi apparatus.





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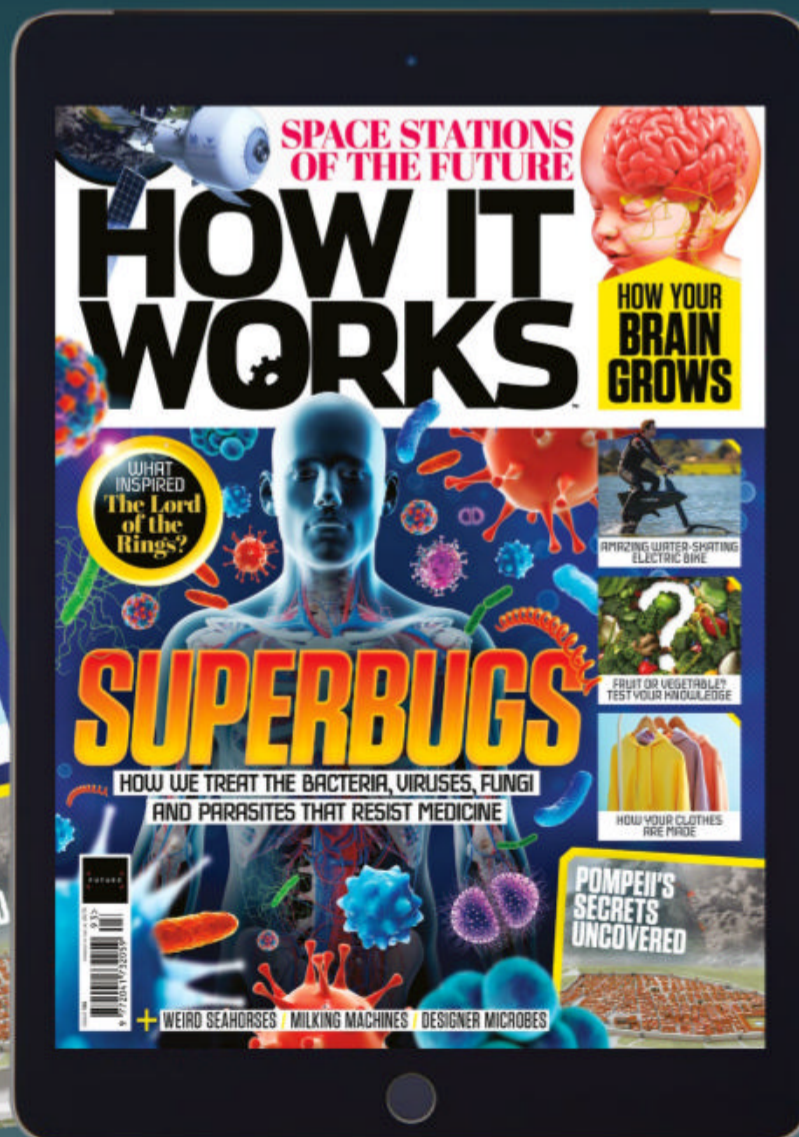
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SPECIAL



RISE OF THE

SUPER

DID YOU KNOW? Global use of antibiotics is expected to rise to 107,472 tonnes by 2030

Bacteria, viruses and fungi are fighting back against our antibiotics. How can scientists defend us from these increasingly dangerous pathogens?

WORDS SCOTT DUTFIELD

One of the greatest threats to humankind's survival is a problem we started over 100 years ago. In 1910 the world's first antibiotic, Salvarsan, was sent out into the world to tackle syphilis, a sexually transmitted infection caused by a bacterium called *Treponema pallidum*. However, the discovery of penicillin in 1928 marked the true beginning of the golden age of antibiotics. Until around the 1970s, the world erupted with new antibiotic medications to tackle a plethora of illness-inducing bacteria. By breaking down

their protective membranes, disrupting their DNA and halting their growth, these medications can make easy work of destroying their targets. However, in the wake of the antimicrobial revolution, a new threat has emerged.

When bacteria, along with viruses or fungi, become resistant to the effects of antimicrobial medicine, it's known as antimicrobial resistance (AMR), with antibiotic resistance being the most common form of AMR. Every antibiotic used in clinical practice now has at least one strain of bacteria that's resistant to it, making them

Did you know?

Bacterium populations can double every 4 to 20 minutes

RESISTANCE

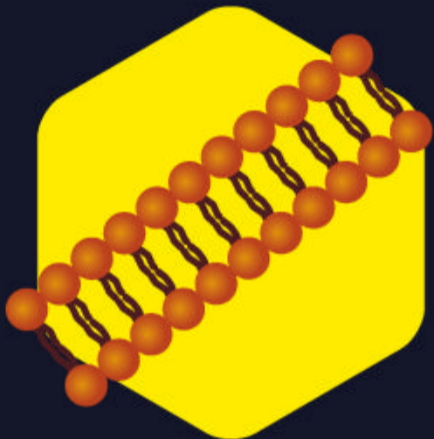
OBLITERATING BACTERIA

How antibiotics take down their microscopic foes



1 HALTING PROTEIN PRODUCTION

Some antibiotics inhibit the production of proteins in bacteria, preventing them from growing, which leads to their death.



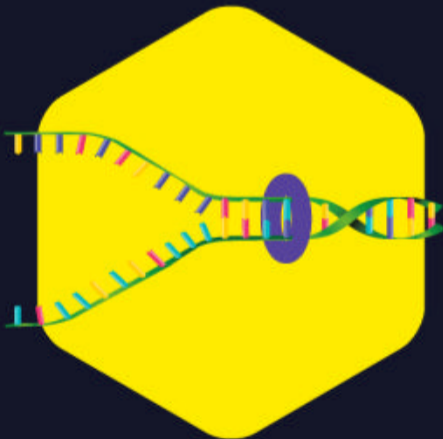
2 DNA DISRUPTION

By binding with the enzyme that transcribes bacterial DNA, some antibiotics stop DNA replication, causing bacteria to die.



3 BREAKING DOWN WALLS

The production of a cell wall-building polymer called peptidoglycan can be inhibited by some antibiotics. This causes the wall to open up, leading to osmotic lysis, where water fills the cell and pops it like a water balloon.



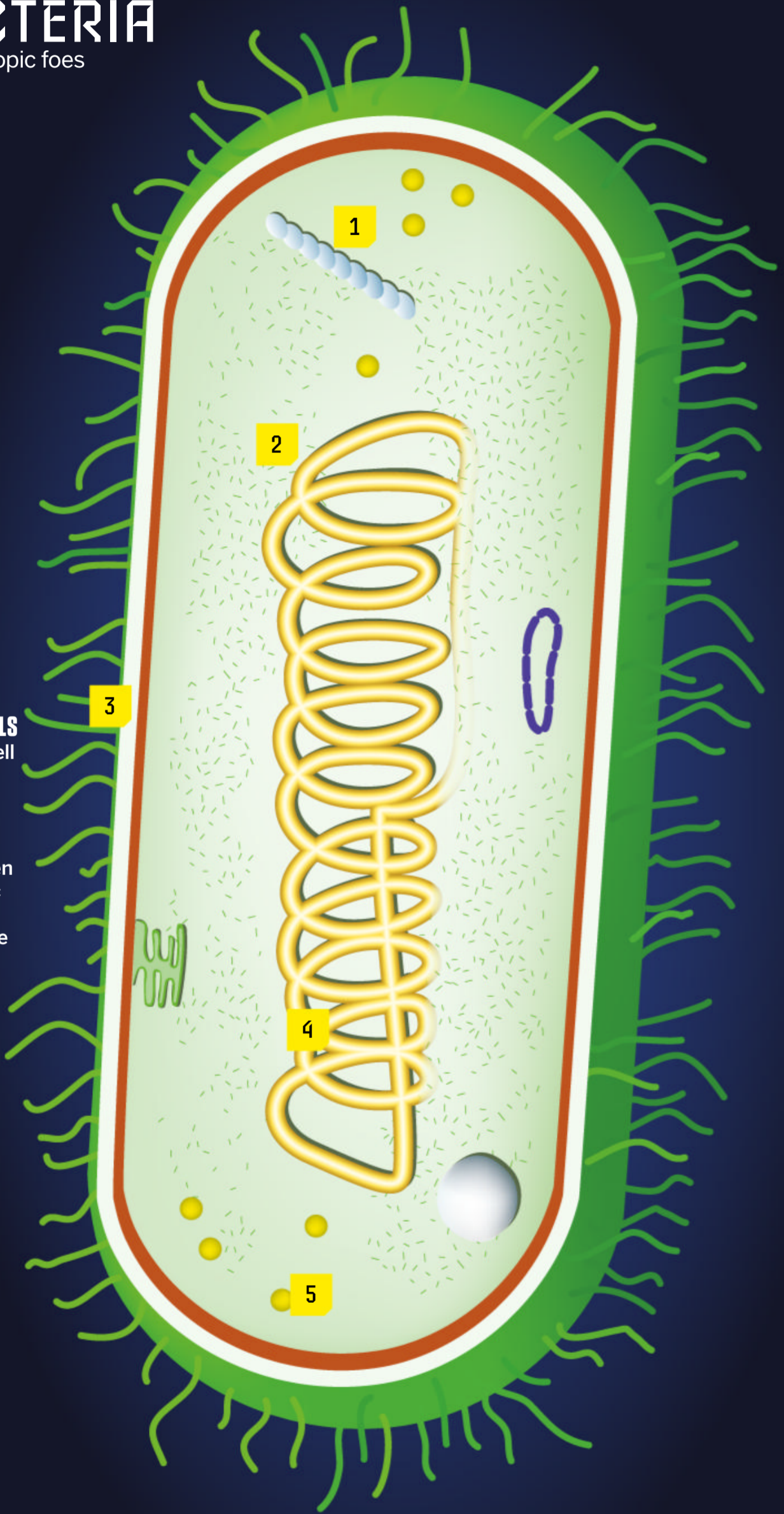
4 MEMBRANE MELTDOWN

Antibiotics can bind to the membranes of bacteria, reducing their functionality and causing them to redirect protein production to the membrane for growth and replication.



5 MESSING WITH METABOLISM

By inhibiting enzymes involved in bacteria's production of metabolites for DNA production, some antibiotics prevent them from growing.



DID YOU KNOW? China is the largest user of antimicrobials in food-producing animals in the world

increasingly difficult to treat. Commonly known as 'superbugs', these defiant microbes get their powers of antimicrobial resistance from mutations in their DNA that lead to changes in the structure of the enzymes, proteins and membranes that antimicrobials target. Some bacteria have even developed 'biochemical pumps' to evict antibiotics that enter their cells.

These genetic mutations, which are often referred to as 'spontaneous resistance', can occur randomly and at any time. Much like the changes that lead to the evolution of any other living organism, Darwin's evolutionary concept of the 'survival of the fittest' is at play here. For example, bacteria that aren't killed by antibiotics because of a mutation go on to multiply and become the remaining dominant strain of bacteria. To make matters worse, bacteria can also share these mutated genes with other bacteria. In a process called 'horizontal gene transfer', circular pieces of DNA called plasmids cross the membranes of bacteria when they come into direct contact with one another.

The other main causes of AMR include the misuse and overuse of antimicrobials. Not completing a course of antibiotics or misusing them can allow bacteria to multiply and form new DNA mutations that lead to resistance. Similarly, antibiotics can be misused to treat symptoms that are caused by another pathogen, like a virus. In a 2017 report released by the World Health Organization (WHO), researchers estimated that just 50 million of the 150 million prescriptions for antibiotics written by doctors in the US were necessary.

One of the most formidable bacteria that has kept scientists on their toes for decades is



An illustration of the superbug fungus *Candida auris*

Did you know?
S. aureus can grow in temperatures between 18 and 40 degrees Celsius

Staphylococcus aureus. As a widely found bacteria in our everyday environments, *S. aureus* doesn't typically cause infection when it comes into contact with healthy skin. However, when this persistent pathogen finds its way into the body's bloodstream or internal tissue it can cause serious infection and can lead to the development of serious complications, such as sepsis and respiratory failure, if left untreated.

Similarly, viruses have found ways to dodge the effects of antivirals by changing their genetic make-up. For example, changes in the DNA of human immunodeficiency virus (HIV) have led to instances of antiviral resistance, stopping this vital medication's ability to block

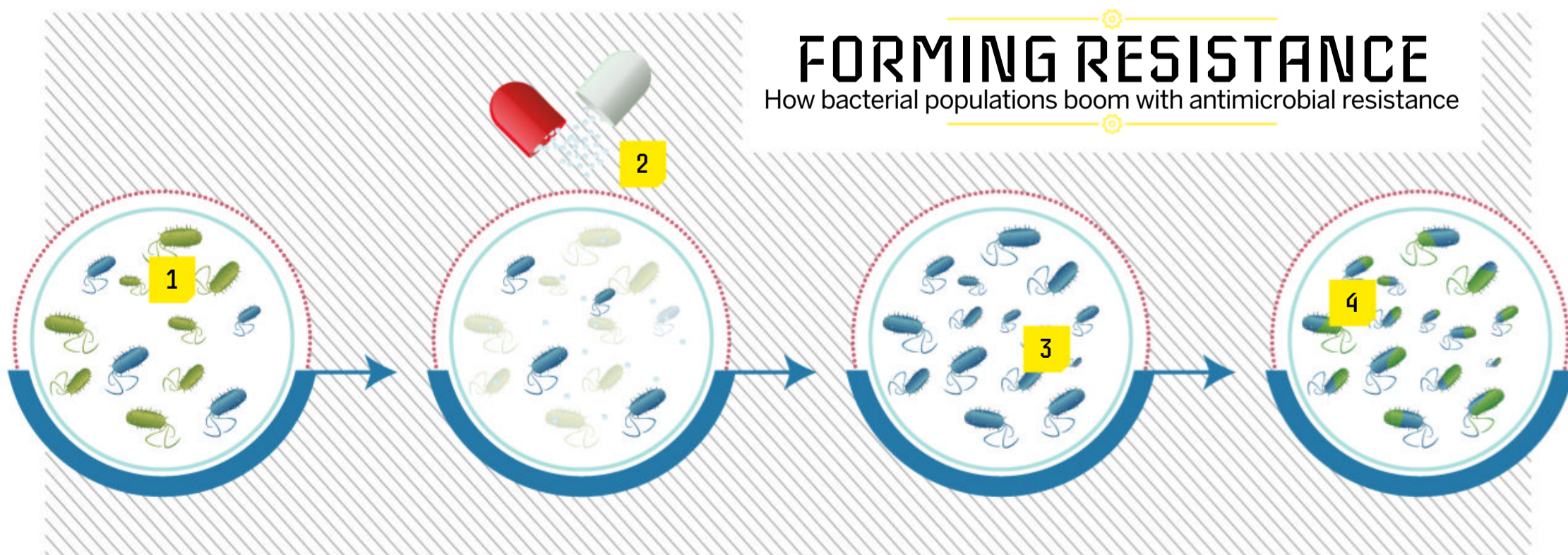


The WHO placed carbapenem-resistant *Klebsiella pneumoniae* at the top of its 2024 AMR priority list

“Viruses have found ways to dodge the effects of antivirals”

FORMING RESISTANCE

How bacterial populations boom with antimicrobial resistance



1 MICROBE POPULATIONS
Microorganisms such as bacteria and fungi grow and spread, causing infection.

2 ANTIMICROBIAL MEDICINE
Medicines destroy the majority of harmful microbes but leave behind any that have mutated a resistance to the medicine.

3 REPOPULATE
The population of resistant microbes grows and spreads, unaffected by medicine.

4 SHARING RESISTANCE
Microbes can share their DNA with other microbes and essentially pass on their resistance.

We'll need to develop new ways to treat infections if current medicine no longer works



virus replication. Among the world's fungi species, *Candida auris* has emerged as a multidrug-resistant yeast that can lead to severe illness, particularly in sick people and those with invasive medical devices. Infections have been on the rise, especially in the US, which between January and December 2022 had 2,377 cases of this variety of superbug infection – a huge increase from the 476 cases in 2019.

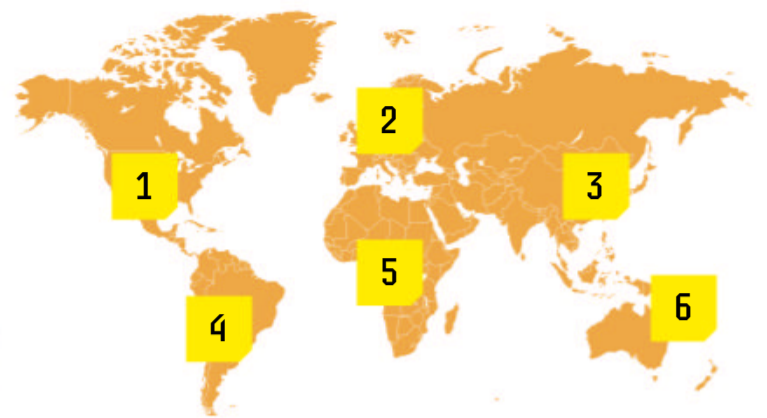
At present, the world is facing its greatest superbug threat, especially in the war against antibiotic resistance. It's estimated that bacterial AMR caused 1.27 million deaths worldwide in 2019 and contributed to the deaths of 4.95 million others. Across the European Union, Iceland and Norway, more than 35,000 die from antibiotic-resistant infections each year.

Superbugs pose an enormous threat, not only to healthy individuals, but for those with existing conditions, especially those who are undergoing surgeries and run the risk of contracting infections that doctors may struggle to treat with antimicrobials. Superbugs can have an effect on global

economies, too. Without mass-produced medicines to take down infections, other more expensive and intensive measures are required to treat infected patients. The World Bank estimates that AMR could lead to \$1 trillion (£800 billion) of additional health costs in the US alone by 2050.

So how do you treat an infection that's become immune to the medicine designed to destroy it? In place of finding a new class of antibiotics – which hasn't happened since the 1980s – scientists have to rely on several other ways to subdue superbugs. From repurposing existing medicines to genetically altering bacteria to fight themselves, scientists have come up with a myriad of ways to ease the threat of AMR. However, one of the most effective ways to stop new superbugs from emerging is by protecting yourself from infection. Maintaining good food preparation hygiene and personal hygiene, especially regular hand washing, can help prevent the transmission of bugs that can cause an infection. Keeping yourself up to date with vaccinations can also help prevent the overuse of antibiotics.

Did you know?
Over 200 viruses are known to cause disease in humans



SMALL BUT DEADLY

The annual predicted deaths attributed to AMR by 2050

1 North America

317,000

2 Europe

390,000

3 Asia

4,730,000

4 South America

392,000

5 Africa

4,150,000

6 Oceania

22,000

THE PERSISTENT RESISTANCE OF MRSA

1944

Penicillin was used to treat *Staphylococcus aureus* for the first time.

1946

Just two years after being treated with penicillin, the first cases of resistance were recorded.

1954

Vancomycin, a new class of antibiotic, was introduced to tackle bacterial resistance.

1959

A new antibiotic called methicillin was first used to combat penicillin-resistant *S. aureus*.

1960

In just a year, strains of methicillin-resistant *S. aureus* (MRSA) were detected.

1997

The first cases of an MRSA strain with reduced susceptibility to vancomycin were reported.

2002

Five years after MRSA showed resistance to vancomycin, the first cases of full vancomycin-resistance occurred.

2003

Daptomycin was introduced to treat skin infections caused by MRSA.

2005

Reports of resistance to daptomycin for MRSA strains emerged.

DID YOU KNOW? Each year the US records more than 2.8 million antimicrobial-resistant infections

TOP-TEN SUPERBUGS

In 2024 the WHO released an update to its 2017 'Bacterial Priority Pathogen List'. The WHO ranks bacterium as a priority on its hit list based on several factors, such as mortality, incidence and treatability, and places them into three groups: critical, high and medium. Here are the top-ten priority bacteria species in 2024



KLEBSIELLA PNEUMONIAE

Ranking in 2024	Ranking in 2017
1	5

DRUG RESISTANCE
Carbapenem-resistant
GROUP
Critical



ESCHERICHIA COLI

Ranking in 2024	Ranking in 2017
2	4

DRUG RESISTANCE
Third-generation cephalosporin-resistant
GROUP
Critical



ACINETOBACTER BAUMANNII

Ranking in 2024	Ranking in 2017
3	1

DRUG RESISTANCE
Carbapenem-resistant
GROUP
Critical



MYCOBACTERIUM TUBERCULOSIS

Ranking in 2024	Ranking in 2017
4	N/A

DRUG RESISTANCE
Rifampicin-resistant
GROUP
Critical



ESCHERICHIA COLI

Ranking in 2024	Ranking in 2017
5	10

DRUG RESISTANCE
Carbapenem-resistant
GROUP
Critical



KLEBSIELLA PNEUMONIAE

Ranking in 2024	Ranking in 2017
6	3

DRUG RESISTANCE
Third-generation cephalosporin-resistant
GROUP
Critical



SALMONELLA TYPHI

Ranking in 2024	Ranking in 2017
7	18

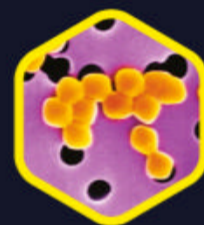
DRUG RESISTANCE
Fluoroquinolone-resistant
GROUP
High



SHIGELLA SPECIES

Ranking in 2024	Ranking in 2017
8	25

DRUG RESISTANCE
Fluoroquinolone-resistant
GROUP
High



ENTEROCOCCUS FAECIUM

Ranking in 2024	Ranking in 2017
9	11

DRUG RESISTANCE
Vancomycin-resistant
GROUP
High



PSEUDOMONAS AERUGINOSA

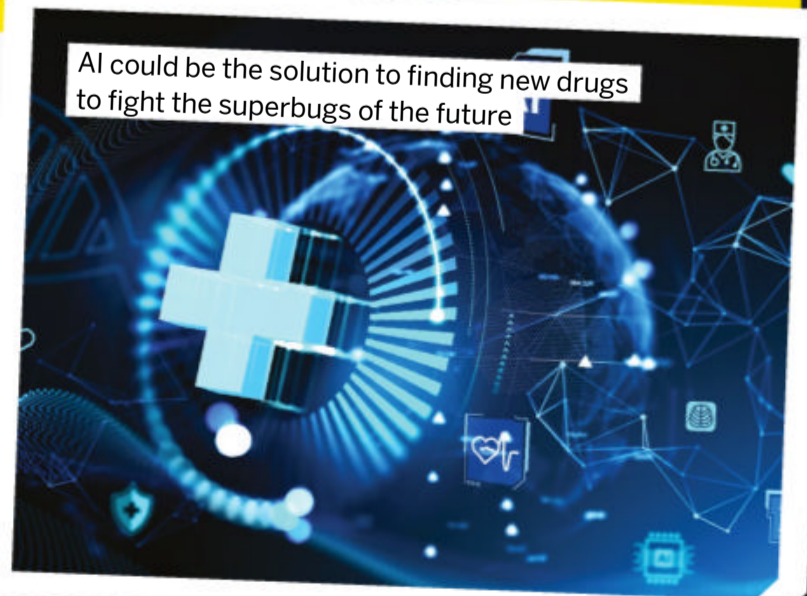
Ranking in 2024	Ranking in 2017
10	2

DRUG RESISTANCE
Carbapenem-resistant
GROUP
High

AI TO THE RESCUE

Artificial intelligence (AI) has proven to be an invaluable tool in finding the antibiotic answers doctors need to tackle superbugs. In 2023, researchers in Canada and the US released the results of a study that used AI to comb through thousands of compounds. These compounds had the potential to be a new antibiotic for a 'critical-threat' bacteria called *Acinetobacter baumannii*. In just an hour and a half, the AI program had sieved through 6,680 compounds and produced a shortlist – nine of which scientists discovered could be potential antibiotics. Due to the rigorous clinical testing potential new antibiotics have to undergo before general use, it's expected that the first 'AI antibiotics' will emerge around 2030.

AI could be the solution to finding new drugs to fight the superbugs of the future

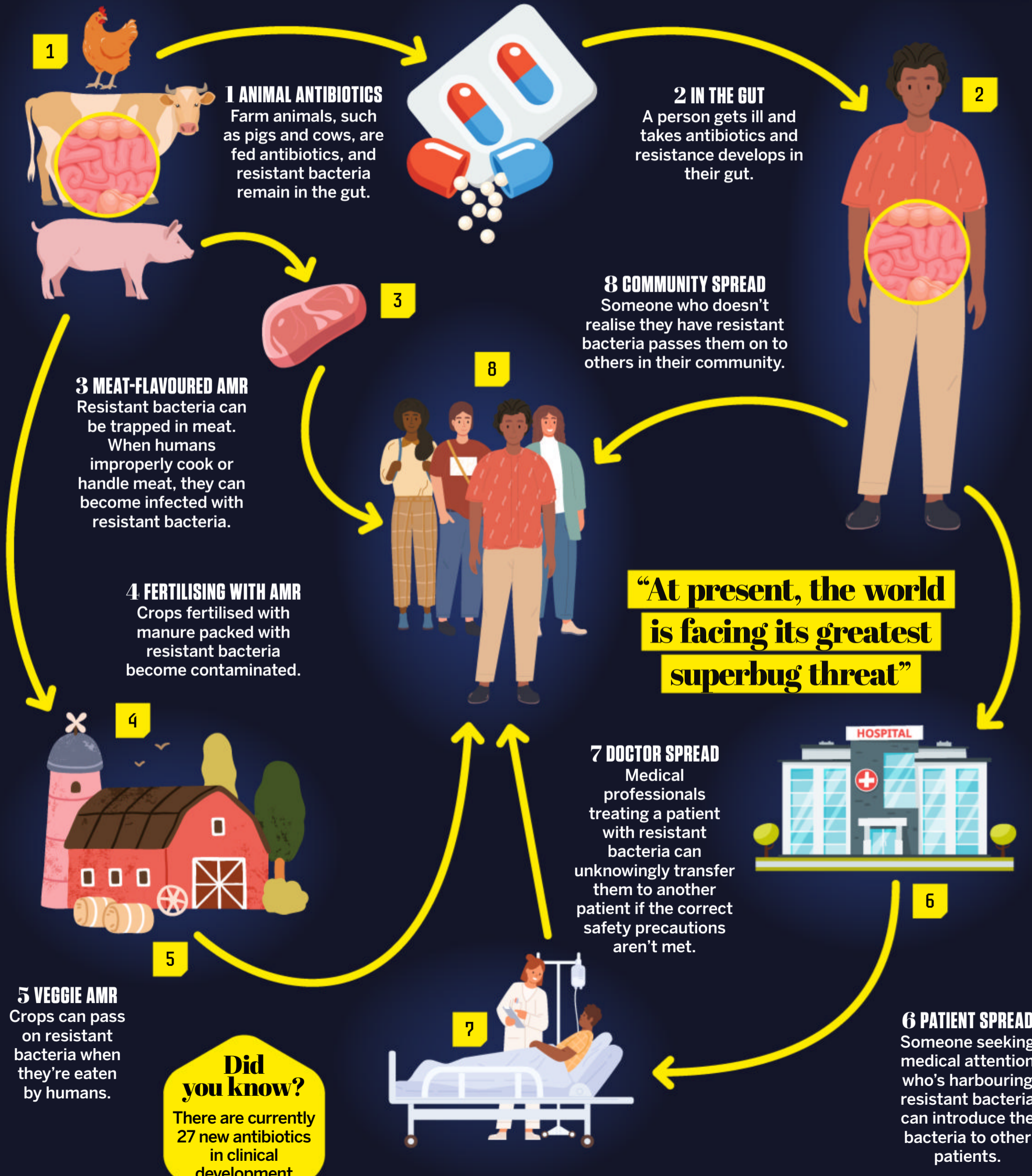




Overuse and misuse of antimicrobials in humans and livestock are the main drivers of the development of AMR

THE SUPERBUG SPREAD

How antibiotic resistance finds its way around the world



“At present, the world is facing its greatest superbug threat”

Did you know?
There are currently 27 new antibiotics in clinical development

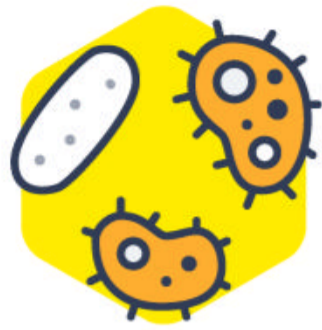
PREVAILING OVER PATHOGENS

This is the medical arsenal doctors can deploy to combat the growing threat of resistance



VACCINES

A helpful tool in fighting the spread of superbugs by blocking their transmission between an infected and healthy person. Curbing the spread of pathogens decreases the chance that one may mutate a resistance to antimicrobial drugs.



BIOTHERAPEUTICS

Doctors can use live probiotics as a way to outcompete AMR bacteria in the gut. Researchers have found that when treating a resilient bacteria called *Helicobacter pylori*, the use of probiotics improved eradication by ten per cent.



PHAGETHERAPY

Using a virus to treat an AMR pathogen might seem like a conflicting idea, but bacteriophage virus theory, or 'phage theory', is a promising path to tackling superbugs. Like sending troops to battle, viruses can be used to find bacteria that might harbour AMR genes, inject them with harmful DNA and ultimately destroy them.



GENETIC ENGINEERING

An emerging tool for tackling bacterial resistance is CRISPR-Cas9, which uses a bacterium's natural gene-sharing habit against it. CRISPR-Cas9 is a technology that allows scientists to 'edit' the genetic information of bacteria, especially the plasmids that they pass between each other.



ANTIMICROBIAL PEPTIDES

By disturbing the membranes of some pathogens, charged peptides, which are short chains of amino acids, can be used as an alternative to other antimicrobials. These are naturally occurring and are derived from many different organisms, such as amphibians, mammals and even insects.



DRUG REPURPOSING

Developing new drugs to tackle AMR is a costly endeavour and can take more than a decade to complete. However, repurposing or modifying existing medicines can deal a fatal punch to AMR infections. This approach comes with mixed success and has been found in some cases to increase AMR in pathogens.

BATTLING THE BUGS

We speak with the European Centre for Disease Prevention and Control (ECDC), who shed some light on how doctors fight superbug infections and how we can help ourselves

How is AMR monitored with so many pathogens in the world?

Data on antimicrobial resistance comes from laboratories that test for infections in humans and animals, and even from laboratories that test bacteria in the environment. This data tells us if the bacteria and fungi from humans, animals and the environment are resistant to treatment to the medicines used for infections with these pathogens. National public health agencies collect data on AMR that originate from laboratories to evaluate what AMR threats – sometimes known as superbugs – are looming.

What are the most effective methods that doctors are using to combat AMR?

Doctors know that taking the wrong antibiotic or taking unnecessary antibiotics can contribute to bacteria becoming resistant. Bacteria evolve to survive their environment, and when they're exposed to antibiotics, they can become resistant. Doctors restrict prescribing antibiotics for infections caused by viruses, as antibiotics don't work against viruses. They also test, when possible, to confirm that an infection is due to bacteria and use information from the laboratory that tells them which antibiotics could be effective for the infection.

What advice would you give people to help in the fight against superbugs?

Everyone has a role in fighting AMR. Antibiotics should be treated with respect: do not self-medicate with antibiotics. If you are prescribed antibiotics by your doctor, take them only in the amount, frequency and duration as prescribed by your doctor. Encourage others to treat antibiotics with respect as well. Controlling the spread of infections can also reduce AMR. Getting vaccinated, washing our hands appropriately and covering our coughs and sneezes all help reduce infections. When we reduce infections, we also reduce the need for antibiotics and the potential spread of resistant pathogens.



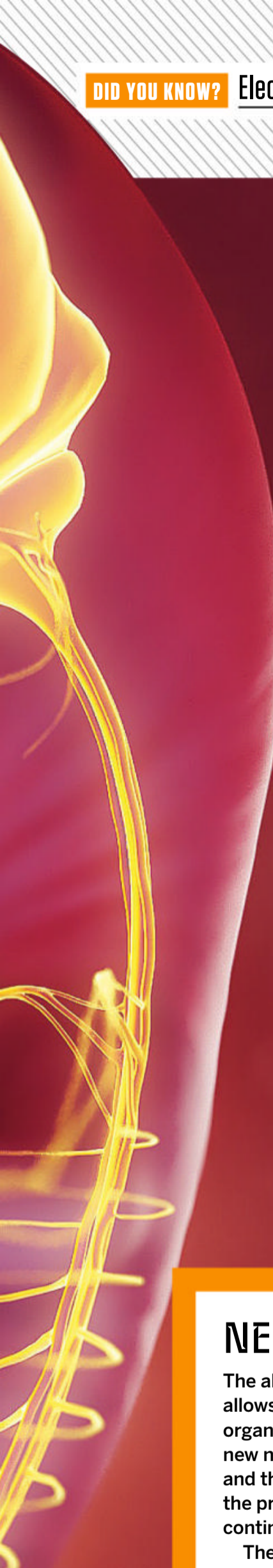
“Bacteria evolve to survive their environment, and when they're exposed to antibiotics, they can become resistant”

HOW OUR BRAINS DEVELOP

Why the way you think changes as your brain grows

WORDS AILSA HARVEY





The brain is the most complex organ in the human body, so it makes sense that it doesn't develop overnight. In fact, to reach its full functionality, it takes most of the first three decades of your life. You use your brain to conjure up every conscious and unconscious thought, automatically control physiological actions like breathing, experience emotions and comprehend sensations. Naturally, everything in the body requires the brain – it produces your personality and is the central computer of your being. The organ itself comprises 60 per cent fat and 40 per cent water, proteins, carbohydrates and salts. The contents are split into white matter and grey matter. White matter is the deeper portion of the brain, containing nerve fibres covered in a protective membrane coating called myelin. Meanwhile, the grey matter is where information is processed, as this contains the central parts of brain cells, called neurons.

Most everyday actions feel automatic to most people. If you need to collect something from the other side of the room, you might walk over and pick it up with minimal effort. However, life doesn't begin like this. Although the brain is formed before birth, ready to navigate life in the world, it lacks the capacity to engage in many simple physical and mental processes. Over the years, pathways in the brain that carry electrical signals become strengthened. Motor pathways, which exist at

the front of the brain in a region called the motor cortex, need to be engaged in order to plan, execute and control voluntary physical movements. When a baby attempts to walk, it perfects the action through trial and error.

The brain uses sensory input to navigate, balance, reposition foot positions and change posture. Different regions of the brain are responsible for different movements, so as neuron pathways are built and strengthened in the brain, the movements available to a person increase. Environmental factors also influence this. Supportive parents and caregivers who encourage their babies to practise moving and walking, or provide words of praise when they take a step, speed up the development of motor skills. Every time an action is practised, more pathways are created in the brain, and the stronger they become.

Your ability to strengthen the brain doesn't stop when you've learned the basics. Every time you train your brain – whether that's taking up a new skill or testing its ability to perform existing skills – the brain's reactive ability and the strength of connections are built. Playing a musical instrument increases grey matter in areas of the brain responsible for motor skills and hearing, for example. Your brain is extremely malleable, continuously shaping itself with new skills, or removing traumatic or useless information. How we treat our brain impacts how its power develops as we interact with the world.

Did you know?

The brain is the fattiest organ

NEUROPLASTICITY

The ability of the brain to change and evolve is called neuroplasticity. This allows it to reorganise neural pathways and create new neurons to grow the organ, form new memories and build intelligence. It was once thought that new neurons were only produced during the early formation of the brain, and that shortly after birth this stopped. However, now scientists know that the production of neurons, called neurogenesis, gradually declines but continues throughout life.

The two types of neuroplasticity are functional and structural plasticity. Functional plasticity is the ability to utilise other areas of the brain for different roles when parts are damaged. Structural plasticity is how the brain changes physically as you learn new things. Neurons have gaps between them for electrical impulses to relay signals and information throughout the brain. These are called synapses, and when you're born you have around 2,500 per neuron. The brain grows rapidly to increase the number of synapses to 15,000 per neuron by the time you're three years old.



A child can pick up a new language quicker than an adult due to greater neuroplasticity



KEY REGIONS

What traits are associated with the development of each section of the brain?

1 FRONTAL LOBE

This is the last part of the brain to mature. It's responsible for controlling an individual's personality and understanding of social norms.

2 PARIETAL LOBE

The development of this region helps a person interpret sensory information and understand their body.

3 TEMPORAL LOBE

When this fully develops, you can effectively process sounds and comprehend language.

6 OCCIPITAL LOBE

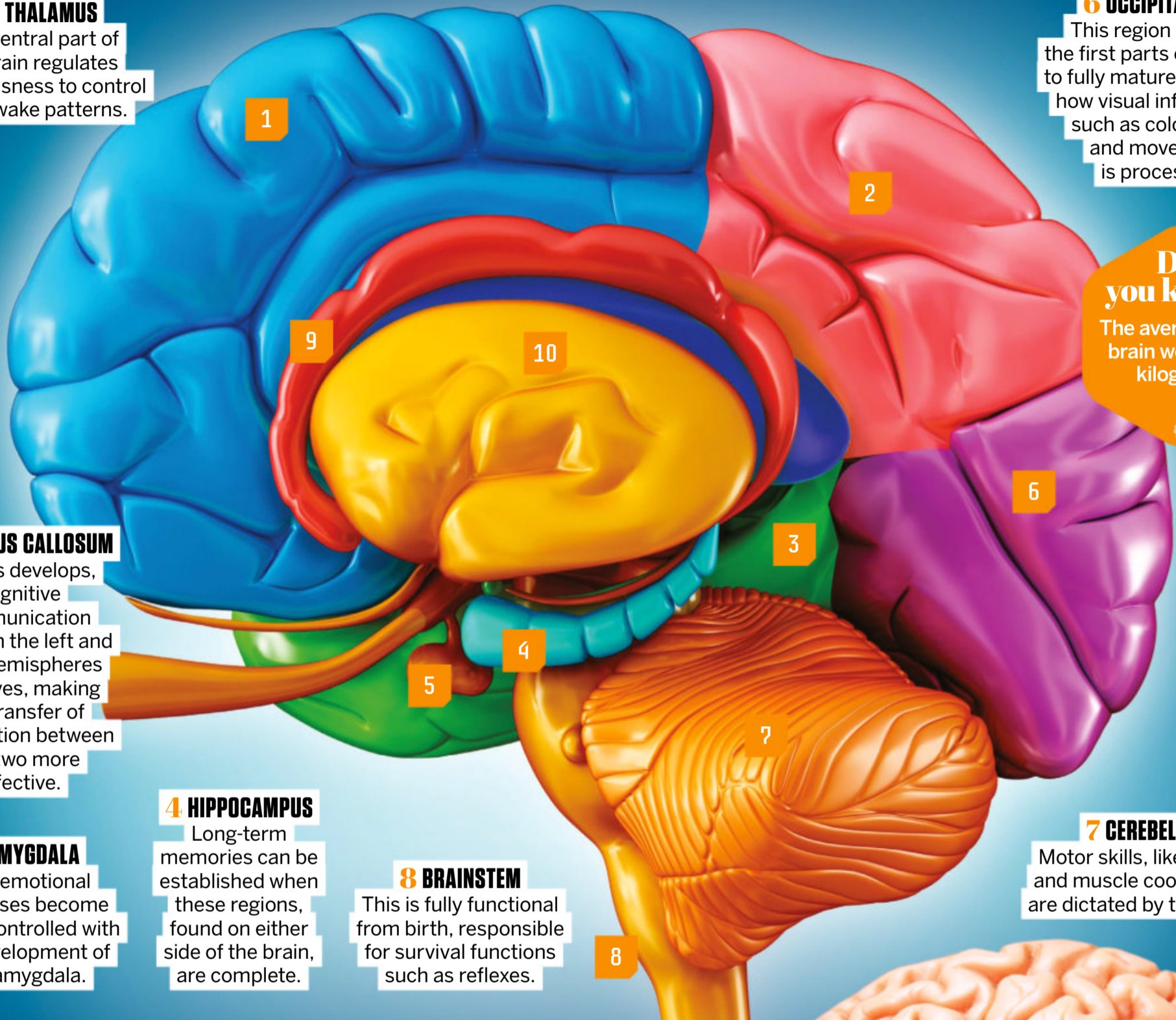
This region is one of the first parts of the brain to fully mature. It controls how visual information, such as colour, light and movement, is processed.

10 THALAMUS

This central part of the brain regulates consciousness to control sleep-wake patterns.

Did you know?

The average adult brain weighs 1.4 kilograms



9 CORPUS CALLOSUM

As this develops, cognitive communication between the left and right hemispheres improves, making the transfer of information between the two more effective.

4 HIPPOCAMPUS

Long-term memories can be established when these regions, found on either side of the brain, are complete.

5 AMYGDALA

Your emotional responses become better controlled with the development of the amygdala.

8 BRAINSTEM

This is fully functional from birth, responsible for survival functions such as reflexes.

7 CEREBELLUM

Motor skills, like balance and muscle coordination, are dictated by this region.

BUILDING AN INTELLIGENT BRAIN

What makes a brain smart? Intelligence is one of the most useful traits in humans. It can help you achieve your goals, apply logic and reason, adapt to new situations and ultimately survive. For these reasons, neuroscientists have studied the structure and activity in intelligent brains in much detail. Some studies have shown that the brains of more intelligent people are wired differently in how regions interact with each other. For example, the anterior insula and anterior cingulate cortex have stronger connections with the rest of the brain. The anterior cingulate cortex works to maintain concentration and decision-making, while the anterior insula controls decision-making and interpreting social cues. Together, they interact with the learning and memory regions of the brain. In addition, research has shown that by the age of 42, a thicker cerebral cortex correlates with higher intelligence. The cerebral cortex is the outer layer of the brain's surface. In children around ten years old, however, it's the surface area of the cerebral cortex that influences intelligence.



The brain's cerebral cortex contains wrinkles and folds, maximising its surface-to-volume ratio

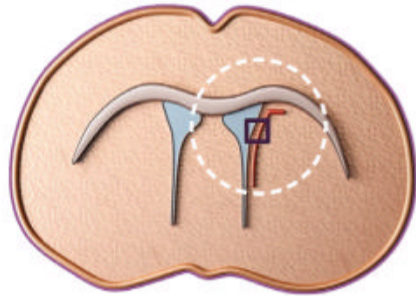
DID YOU KNOW? A piece of brain tissue the size of a grain of sand contains 100,000 neurons

HOW NEW CELLS ARE MADE

Neurogenesis is a process that takes place along the walls of the subventricular zone, spanning across the central part of the frontal, parietal, temporal and occipital lobes

1 EPENDYMAL CELL

Lining the brain's ventricles, these support stem cells as a barrier to control the surrounding fluids.



2 BLOOD VESSEL

Blood carries oxygen and nutrients towards the cells and waste products away from them.

3 NEURAL STEM CELL

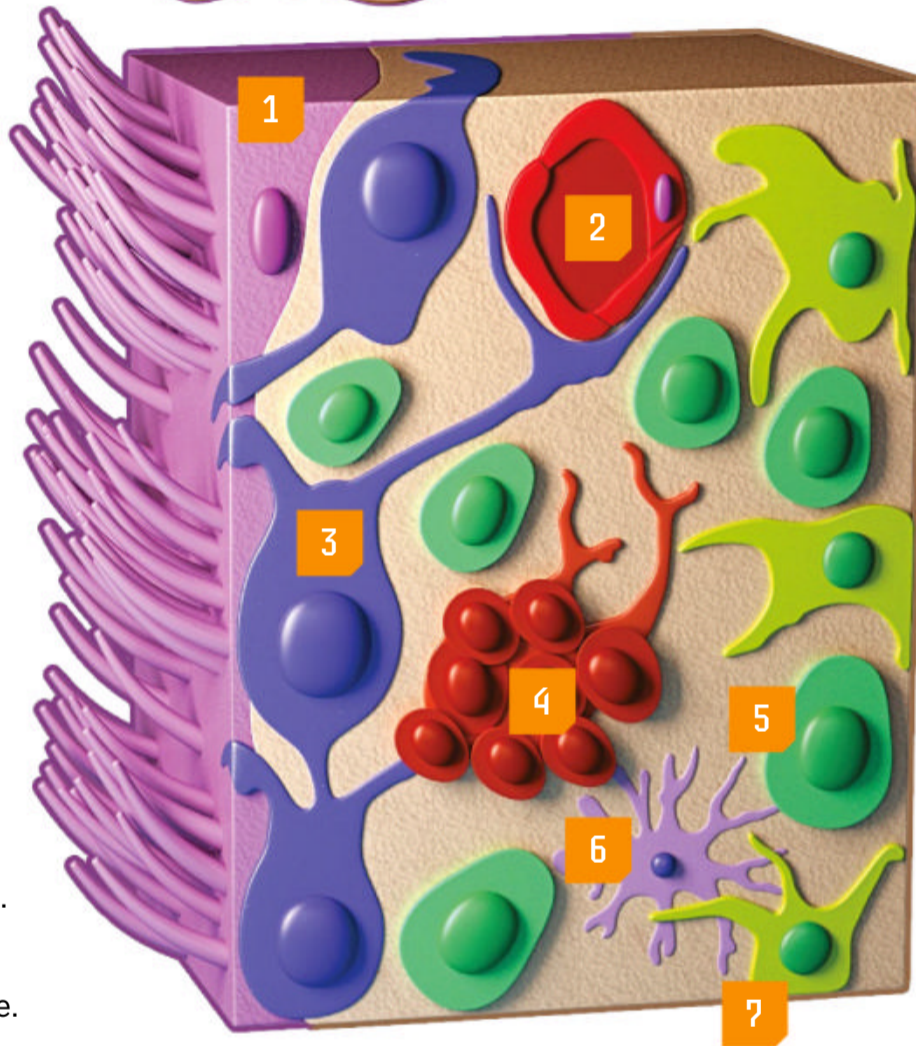
These have the ability to change into any specific type of brain cell needed.

6 MICROGLIAL CELL

These support cells patrol the brain in search of damaged or dead cells. Microglial cells eat damaged cells to maintain brain health and can recycle any useful nutrients.

7 INTERMEDIATE PROGENITOR CELL

IPCs are in the first stage of differentiation. They haven't fully matured, but have committed to a cell type.



4 NEUROBLAST

Neuroblasts are cells that have begun to develop into fully functional neurons. They migrate through the brain until they mature into part of the brain's circuit.

5 TRANSIENT AMPLIFYING CELL

These are released by stem cells. They play the same role as neural stem cells, but can divide more rapidly to become mature cells.



5 FACTS MALE VERSUS FEMALE

1 BRAIN PROPORTIONS

A male brain generally has a larger inferior parietal lobule – part of the brain linked with time and speed estimation. A female has larger areas of the brain responsible for language.

2 WHITE:GREY

Female brains have ten times more white matter than male brains, but a male's brain has 6.5 times more grey matter. White matter is essential for communication and grey for information processing.

3 CONNECTIVITY

A male brain has better communication within the hemispheres, while a female brain has better connectivity between the two.

4 CHEMISTRY

Some hormones and neurochemicals in the brains of males and females are processed differently. The mood-stabilising chemical compound serotonin has a 52 per cent higher production rate in male brains.

5 MEMORY STORAGE

Parts of the brain relating to memory storage are larger in female brains. This makes women more likely to remember accurate details of events that occurred a week ago.

STARTING TO SHRINK

As with the rest of the body, the brain begins the ageing process upon reaching adulthood. When you reach your 30s and 40s, the brain starts to decrease in volume. The frontal lobe and hippocampus shrink at a faster rate than other regions of the brain. The shrinking of the frontal lobe affects memory, emotions and impulse control in older age, while the change in hippocampus size hinders motivation and learning regulation. Other natural changes in the brain in later life include the thinning of the outer surface, reduction in nerve fibres that transmit signals between brain cells and changes in chemical production that keep the brain functioning optimally. Despite the fact that you naturally lose brain cells throughout adulthood, this is a very gradual process for most. When some regions lose mass, others can adapt and take on new roles to maintain efficiency.

After 40 years of age, the brain starts to shrink about five per cent each decade





A baby's brain is highly receptive to sensory input



Did you know?
A three year old's brain is twice as active as an adult's



This microscope image shows myelinated nerves

CONCEPTION TO FULL COGNITION

Your brain is constantly evolving, reaching full maturity at around 25 to 30 years old

1 EARLY DAYS

The brain's early structure, the neural tube, forms in the womb. At 35 days, the structure has fused to form a tube. The foetus is six to seven millimetres in length and the early structures of the brain and spinal cord are visible. The brain can already process sensory information like sound, touch and light.

2 TAKING SHAPE

The forebrain, midbrain and hindbrain form into three distinct structures. Neurons form at a rapid rate of 15 million per hour, building structure and activity within the brain. As the newly made neurons migrate to different parts of the brain, the foundations of complex neural pathways are established.

The brain is 25 per cent of its adult size when a baby is born. It has 100 billion neurons and 50 trillion synapses.

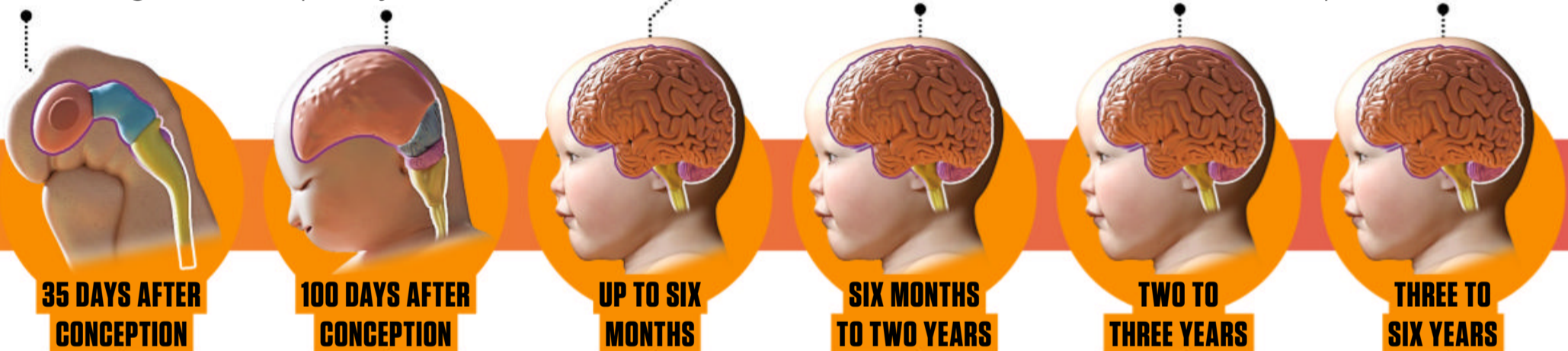
By two years old, the brain is already at 80 to 90 per cent of its adult size. This helps the infant learn many new skills in a relatively short time. The motor cortex in the frontal lobe grows significantly, enabling the planning, control and execution of physical movements.

5 LEARNING LANGUAGE

The brain makes sense of words and begins to organise them into sentences. Being able to speak in short sentences helps a child better express their wants and needs. As the brain picks up on the same words being used and repeated, it uses memory to make links and understand their meaning.

6 SOLVING PROBLEMS AND MAKING MEMORIES

The brain evolves to develop basic problem-solving skills, object categorisation and memories. This occurs because the brain is becoming more connected and enables multiple regions to engage in more complex thought processes. This includes working out cause-and-effect patterns.



35 DAYS AFTER CONCEPTION
The forebrain is the largest and most complex part of the newly formed brain. The higher cognitive functions take place in this part of the 35-day-old brain. It includes the cerebral cortex, thalamus, hypothalamus and basal ganglia.

100 DAYS AFTER CONCEPTION
The forebrain starts to take a larger, rounded shape, differentiating itself further from the other parts of the neural tube.

3 NEURAL CONNECTIONS
From birth, the brain undergoes rapid growth as new neurons are made. As it explores the world it has entered, a baby develops new neural connections. This causes the brain to double in size within the first year of life. By birth, a baby already has the basic reflexes to increase its chances of survival.

4 MOTOR SKILLS
By six months, a baby can sit unsupported, and by around 12 months begins to walk. Alongside these large movements, children this age develop fine motor skills, such as holding and stacking objects. Between 9 and 12 months, an infant's brain starts to comprehend object permanence. This is the understanding that objects continue to exist even when out of sight. During this period of life, the brain is constantly adding neural connections.

TWO TO THREE YEARS
At ages two to three, the number of synapses reach their highest levels. Synaptic pruning takes place to improve the brain's efficiency. This means that extra and unnecessary neurons and synapses are eliminated. These include synapses that are rarely used and become weak. The brain activity they're associated with isn't needed and can be replaced.

THREE TO SIX YEARS
One of the changes at this stage that improves the efficiency of thought processes and the ability to problem solve is myelination. This is when a myelin sheath, made of fat and protein, forms around nerves in the brain. Myelination improves conduction and sends electrical signals quicker throughout the brain.

By around the 24th week of pregnancy, scans show that babies move in response to sound



A child's brain uses touch, vision and spatial awareness when stacking objects



DID YOU KNOW? 60 per cent of a baby's energy goes into brain development

“Every time an action is practised, more pathways are created in the brain, and the stronger they become”



Teenagers are thought to be more likely to take risks with unknown consequences than other age groups

7 LOGICAL THINKING AND CATEGORISATION

During these years, children enter the concrete operational stage of brain development. They become better at understanding events concerning other people and not just those they are directly involved in and experiencing. Some key features of the concrete operational stage include recognising that when an object changes size, volume or colour, it still keeps many of the same characteristics. Also, children are able to place items with matching characteristics into groups.

As pruning and myelination continue, neurons that are responsible for more complex thought processes are being strengthened. This helps a child single out relevant stimuli around them.

9 RISKY DECISIONS AND IMPULSE CONTROL

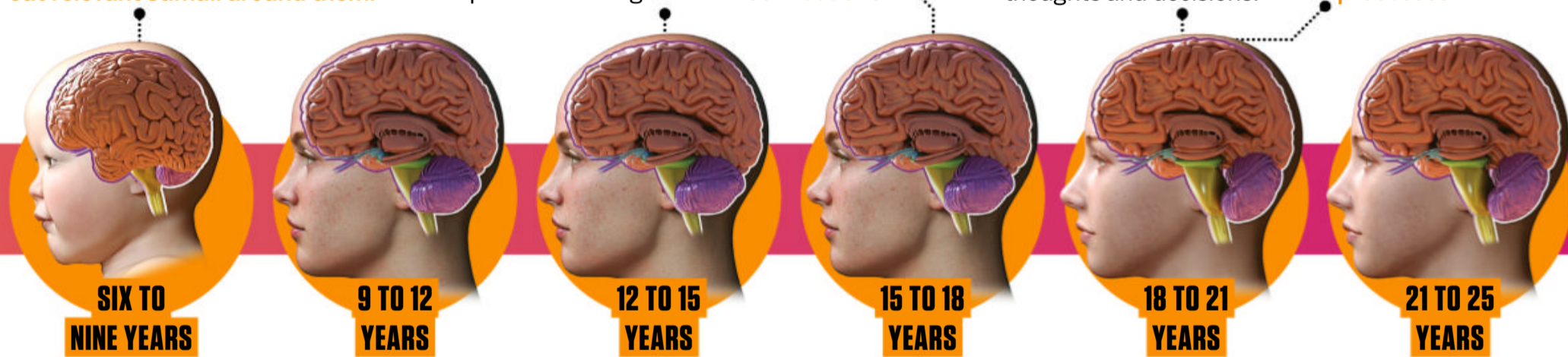
Teenagers get a bad reputation for making unwise choices, but there's a explanation. Puberty affects the entire body – brain included. New hormone levels cause more fluctuations in mood and impulsive behaviour. But the brain gets smarter too, developing a longer attention span, heightened abstract thinking and complex problem-solving.

As the limbic system matures and settles post-puberty, it becomes better at processing emotions and responding to the reward chemical dopamine that is released through romantic connections.

11 INCREASED SELF-ASSURANCE

At this stage, the brain is reaching peak maturity and the beginning of adulthood. This makes a person more trustworthy in making responsible decisions, better at planning for their future and confident in their own thoughts and decisions.

Grey matter, which contains the brain's cells and capillaries, reduces in size. Although the brain loses neurons, this makes the brain more efficient as there is more space for myelination. The brain is being refined to strengthen the most useful thought processes.



8 SOCIAL AND EMOTIONAL GROWTH

At this stage in life, an individual starts to display increasing signs of empathy as their brain becomes more emotionally intelligent. Building from past personal experiences and developing an understanding of the events that can cause different feelings, children between these ages are able to act more sensitively. Stronger friendships are generally formed at this stage of school life.

The frontal lobe reaches adult size. This increases the ability to form interpersonal relationships and manage emotions. The frontal lobe helps a person process positive emotions like happiness and gratitude and negative emotions like anger and jealousy.

During puberty, the limbic system releases more hormones like oestrogen and testosterone. This rapidly developing part of the brain makes teens more likely to act on impulsive decisions and seek pleasure. The quickly evolving limbic system is in a state of imbalance compared to the more gradual progression of the prefrontal cortex, responsible for rational decisions. As a result, impulsive thoughts outweigh logic more often.

10 FORMING SELF-IDENTITY

The brain matures further during these years, giving individuals greater ability to reflect on experiences, behaviours and thoughts. Older teenagers are more capable of making decisions oriented towards the future. Maturation in emotional regulation also helps build romantic interest, as they can process stronger feelings better.

12 FULL MATURITY

Around these ages, your brain reaches full cognitive maturity. The brain is at its strongest in terms of critical thinking, performance and decision making. From this point, a person's cognitive skills remain relatively consistent. There is gradual decline as the years pass, but healthy eating and mental and physical exercise keep your brain thriving far into adulthood.

After maturity, the hippocampus makes new brain cells at a slower rate. The frontal lobe matures until around 25, at which point it is fully developed.

Mirror neurons fire signals when the individual performs an action and observes someone else performing the same action

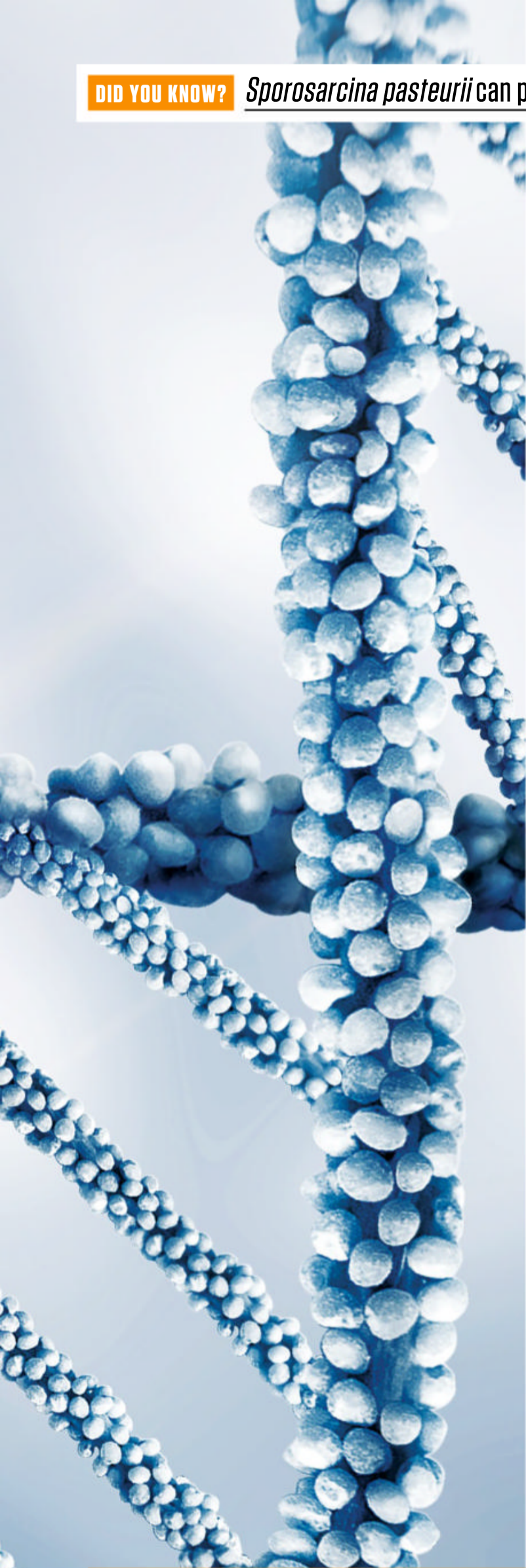


DESIGNER MICROBES

How altering the genes of tiny microbes can make them produce insulin for diabetics, strengthen cement and even make street lights

WORDS AILSA HARVEY





Microbes are extremely versatile microscopic organisms that include bacteria and viruses. Unseen by the naked eye, they conduct chemical conversions on a tiny scale, keeping the planet alive by recycling nutrients, both causing and preventing disease, but generally playing a vital role in our living planet. Some thrive in extreme environments, while others are carried with us at all times. There are 39 trillion microbial cells covering your body, maintaining your immune system and daily processes like digestion.

As small organisms, microbes have simple genetic structures, making them easier for scientists to study. By gaining a more thorough understanding of what different sections of DNA control within a microbe, scientists can alter them to favour certain traits. These are genetically engineered

microbes – dubbed ‘designer microbes’. Microbes grow rapidly and multiply quickly. This enables desirable new genes to be mass produced. In many projects involving modified microbes, DNA from other organisms – including human DNA – can be incorporated into that of a microbe, like bacteria. When these bacteria reproduce, over time large volumes of human genetic material is generated. This can be used to produce medical treatments for people whose own cells don’t naturally produce enough of a specific biological compound in the body.

The possibilities for designer microbes are expanding, and today research into their applications spans industries from medical and food to construction and textiles. Here are some of the most successful, inventive and futuristic applications of designer microbes.

Did you know?

Bacteria was the first genetically modified organism

BUILDER BACTERIA

Meet the bioengineered bacteria that have been called up for assistance in construction



Escherichia coli
CEMENT STRENGTHENER

E. coli can be modified to make more of the enzymes responsible for converting calcium and carbonate ions into calcium carbonate. *E. coli* in concrete strengthens the mixture, as the calcium carbonate fills any gaps.



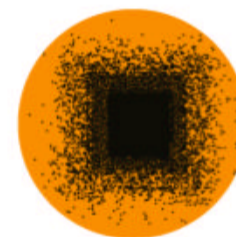
Bacillus subtilis
CONCRETE SELF-HEALER

This releases spores into concrete. If dry concrete cracks, moisture is able to seep through and reach dormant spores so they can germinate, producing calcium carbonate crystals that seal the cracks.



Sporosarcina pasteurii
BIOBRICK INSULATOR

S. pasteurii is genetically engineered to produce thermally insulating compounds. These fill gaps in concrete bricks, slowing heat loss from buildings.



Synechococcus elongatus
BUILDING SITE DECOMPOSER

One application of this bacteria is for construction cleanup. It is engineered to improve its ability to degrade pollutants. For example, it can make proteins that bind to heavy metals at construction sites.



Myxococcus xanthus
BIOFILM LAYER

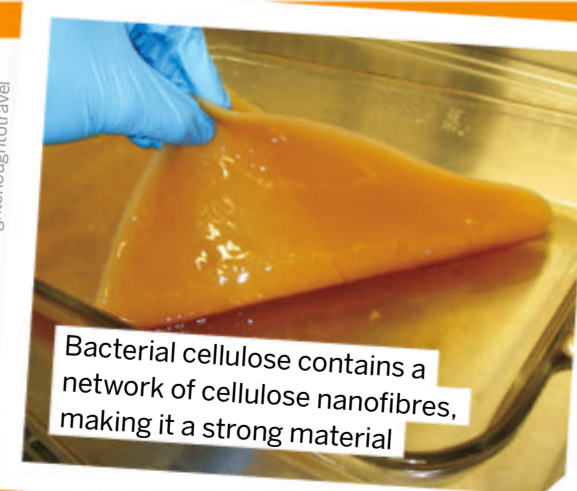
This forms complex biofilms over surfaces, but can be modified to improve its ability to cling to materials used in construction. The living layer makes materials more adhesive and helps prevent water damage by repelling water.

SELF-DYEING LEATHER

In an effort to make leather production more sustainable, scientists have modified bacteria to release a melanin-producing protein. This bacteria is *Komagataeibacter rhaeticus*, and after being genetically modified it expresses the gene tyrosinase-related protein 1. This produces the pigment eumelanin, which is dark brown or black

in colour. This bacteria naturally produces cellulose, and along with its modified genes, this cellulose is leather-coloured, making it an ideal replacement for the animal skin material. This bacterial species produces the cellulose in strong, flexible and malleable sheets, ideal for textile purposes.

© Wikimedia Commons/Lightenoughtotravel



Bacterial cellulose contains a network of cellulose nanofibres, making it a strong material

© Shutterstock

PLANT STREET LIGHTS

£88,500 (\$114,300) is spent per year per mile of street lighting used in the UK. These lights are expensive and use electricity throughout the night. However, new techniques are being explored to harness the natural bioluminescent qualities found in nature to produce a more natural variation of the common street light. Bacteria that contain an enzyme called luciferase naturally illuminate when a biochemical reaction takes place. Luciferase works to oxidise the substrate luciferin in the organism – a reaction that requires oxygen and causes the substrate to glow. Bacteria that glow do so to help themselves be dispersed: they can usually survive in the digestive tracts of animals, so attracting animals to them helps them be ingested and relocated.

Scientists have demonstrated that the genes responsible for producing luciferase and luciferin can be cut from bioluminescent bacteria and inserted into the genes of evergreen plants. The genes of the bacteria can be modified to alter their metabolic processes and sensory cues so that they produce more light and are consistently glowing when darkness falls. The plants that these genes are inserted into need to be strong to reduce the chance of damage, and also evergreen so that their leaves glow all year round. *Prunus lusitanica* is one such tree species being explored in research.



The enzyme luciferase is not naturally present in plants

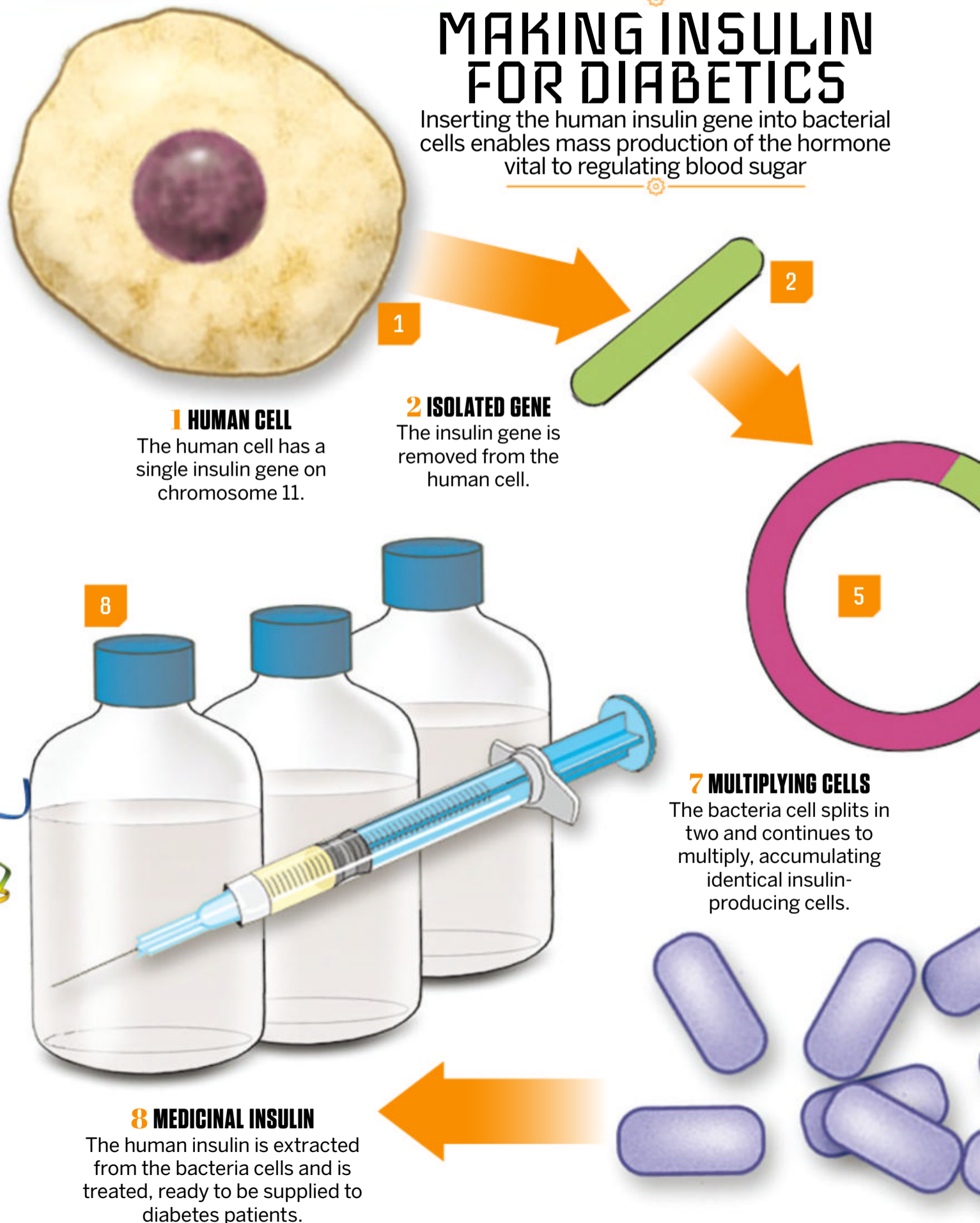


In US waters, there are over 150 oil spills a year

Did you know
200 million people rely on insulin therapy

MAKING INSULIN FOR DIABETICS

Inserting the human insulin gene into bacterial cells enables mass production of the hormone vital to regulating blood sugar



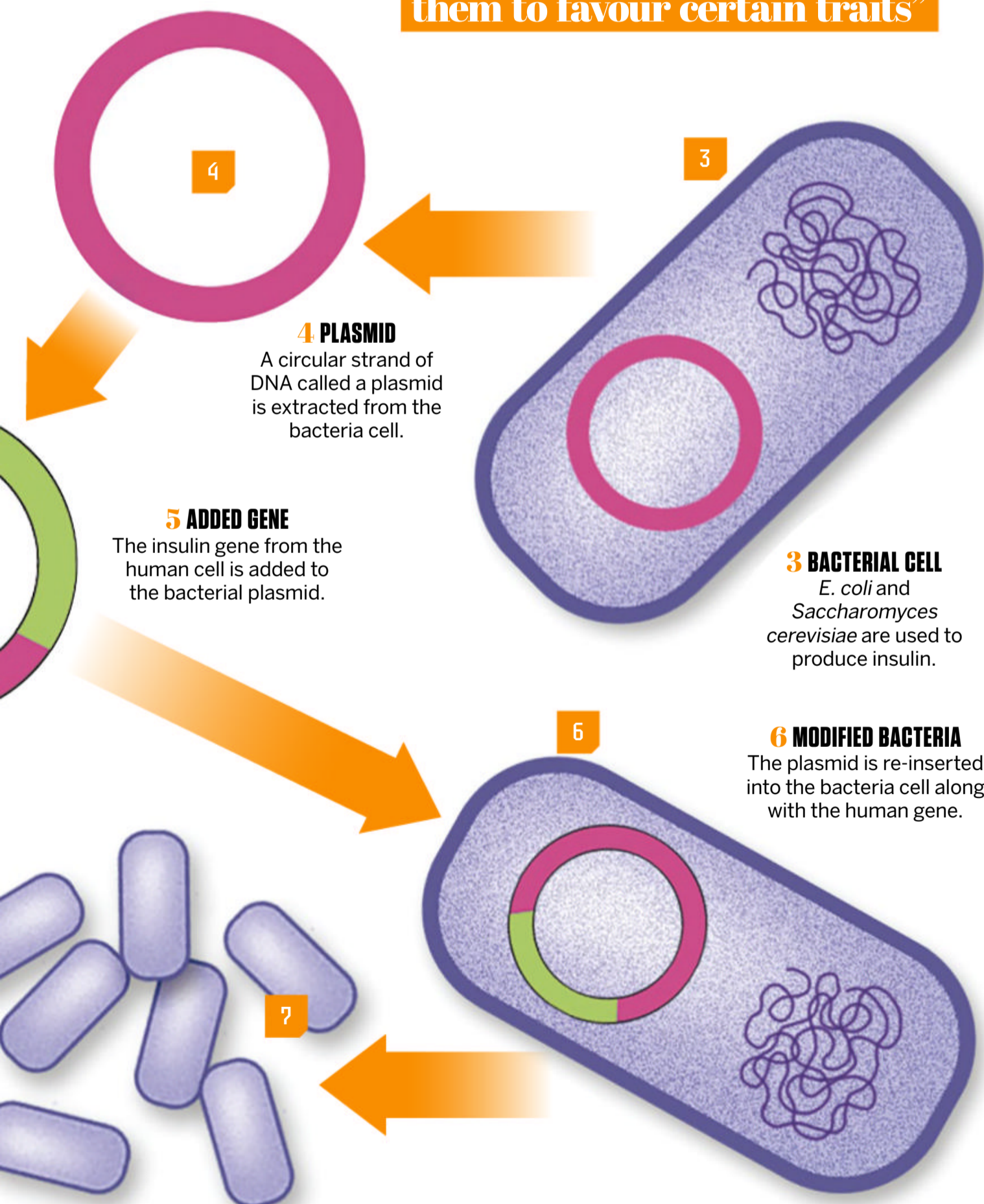
DID YOU KNOW? Under optimal temperatures, *E. coli* can reproduce in as little as 20 minutes

OIL-SPILL EATERS

Around 9 million tonnes of oil enters the world's oceans each year, polluting marine environments. Many of the spills come from drilling rigs, tankers, storage facilities and pipelines. The main pollutants in these spills are hydrocarbons – compounds that contain hydrogen and carbon. Hydrocarbons remain in the water for many years, killing wildlife with their toxic chemicals and sinking to the

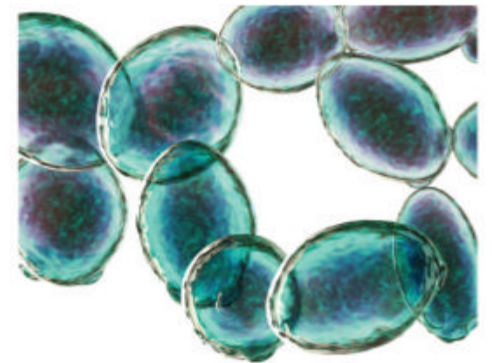
seafloor to contaminate sediment. In addition, they are poisonous to humans. The minute microbe facing the mighty cleanup task in polluted seas is called *Pseudomonas putida*. The bacteria's plasmids are genetically modified to alter their metabolism, allowing them to break down and feed on the masses of complex hydrocarbons tainting the seas.

“Scientists can alter them to favour certain traits”



BOOSTING BIOFUEL

How editing yeast produces ethanol for an eco-friendly alternative at the fuel pump



1 ENGINEERING YEAST

During fermentation, yeast converts the sugar from food waste into ethanol. This yeast is genetically modified to increase its tolerance to the ethanol it produces.



2 FERMENTING FUEL

The enzymes in the yeast convert glucose into ethanol, carbon dioxide and water. This process requires controlled conditions, with no oxygen present and warm temperatures of 25 to 35 degrees Celsius.



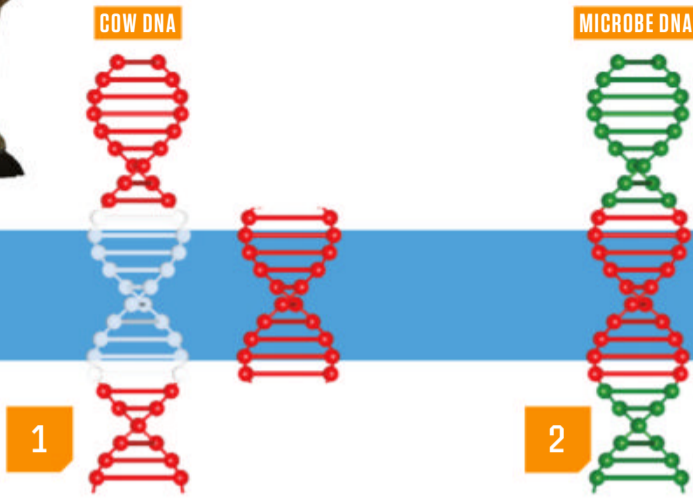
3 ETHANOL EXTRACTION

The ethanol is extracted from the bioreactor to be added to gasoline fuels. Because the yeast was modified, higher concentrations of ethanol can be produced before the yeast stops working.



1 COW DNA EXTRACTION

The genes responsible for producing dairy proteins and other milk components are isolated from a dairy cow's DNA.



2 MODIFYING MICROBES
The milk-producing genes are inserted precisely into microbial DNA so that the host can read the new instructions.

MAKING MILK WITHOUT COWS

How microbes could take over the dairy production line

4 CELL SHRINKING

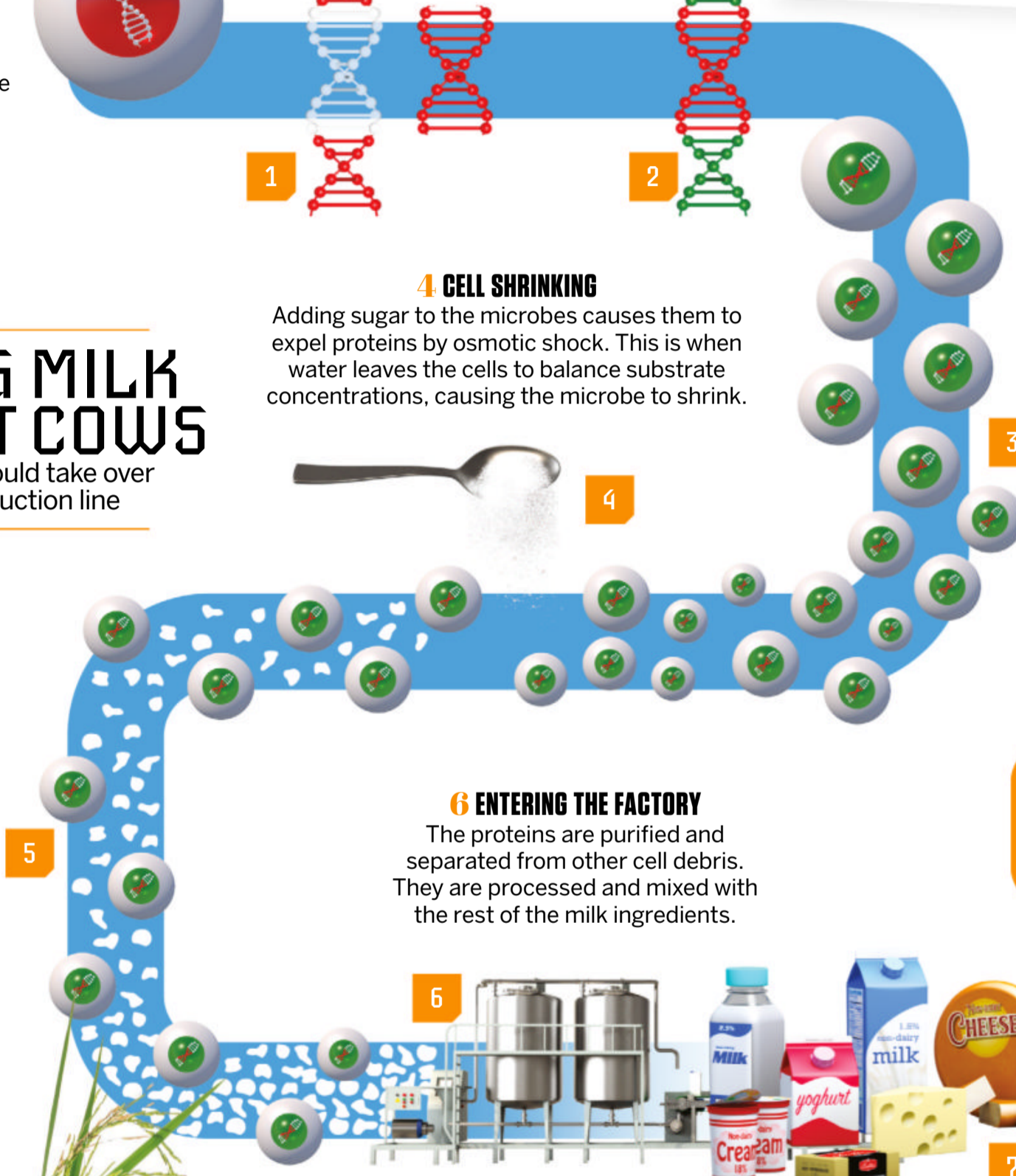
Adding sugar to the microbes causes them to expel proteins by osmotic shock. This is when water leaves the cells to balance substrate concentrations, causing the microbe to shrink.



3 MICROBE MULTIPLICATION
The microbes reproduce. Each one is copied to contain the DNA instructions for making dairy proteins.

5 PROTEIN COLLECTION

As a stress response to shrinkage, the microbe releases its contents, including the dairy proteins.



6 ENTERING THE FACTORY

The proteins are purified and separated from other cell debris. They are processed and mixed with the rest of the milk ingredients.

Did you know?

Saccharomyces cerevisiae isn't affected by microgravity



7 FINISHED PRODUCTS

The resulting dairy products have the same taste, texture and nutrients as those in cow's milk.

PIONEERING ENGINEERING

For the first time, research published at the beginning of 2024 shows that scientists have engineered the microbiome of a plant. The microbiome of an organism is the community of microbes covering it. In a plant, this protects it from disease and influences the nutrients available to it. When modifying a rice plant's microbiome, scientists increased the population of beneficial

bacteria by editing one gene. Plants with this healthy new microbiome are less reliant on pesticides that are damaging to the environment. Within a complex molecule of the plant's cell walls, called lignin, the team of scientists found one gene that directly influences the microbiome. When they overexpressed the gene, the result was an influx of these beneficial microbes.

There are billions of microbes in a rice plant's microbiome

REDUCING BEER BITTERNESS

One of the processes in which genetically modified microbes are used to influence a product's taste is beer fermentation. Yeast is used to ferment sugars and turn them into alcohol for beverages. But the extra roles of these microbes can be controlled through changing their genes. As well as providing the alcohol content, yeast can be modified

to express different enzymes depending on their roles. Some of the enzymes made by yeast break down bitter compounds in beer. Overexpressing the genes responsible for this enzyme's production will increase the number released into the beer batch, making a milder tang and creating new flavour profiles.



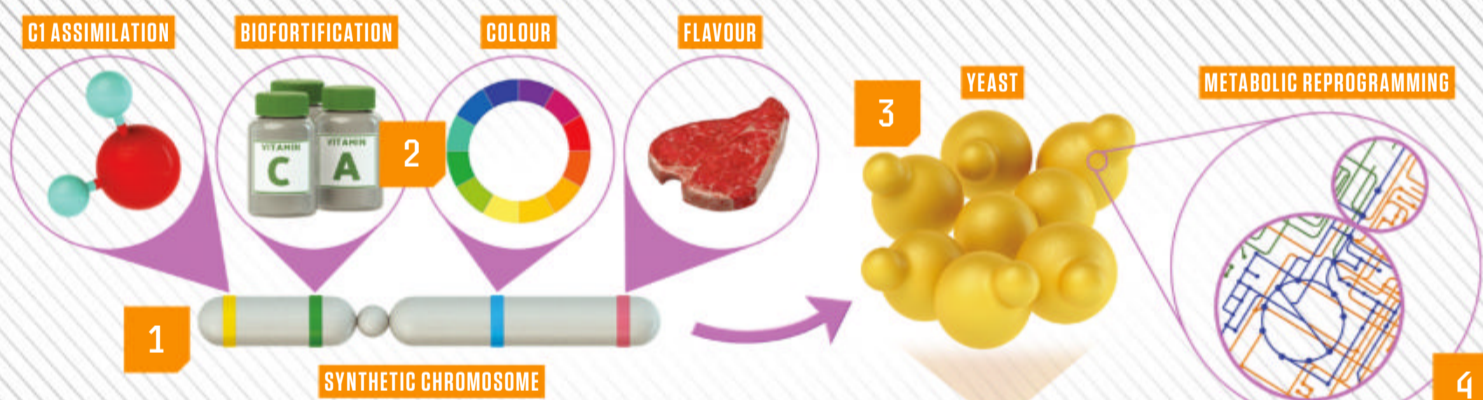
Yeast content influences a beer's taste and aroma

3D-PRINTED MEALS

NASA is working on ways astronauts could make a range of nutritional foods in space from yeast

1 SYNTHETIC CHROMOSOME

A synthetic chromosome is built from natural components that can be inserted into a cell. In this case, the genes contain instructions to produce a specific food's traits.



2 SENSORY ATTRIBUTES

Some of the genes that need modifying include those responsible for carbon assimilation, nutrient production, colour and flavour. Carbon assimilation ensures that compounds with a single carbon atom can be used by the yeast for its growth so waste gases in space can be used up.

3 YEAST

The new traits then need to be genetically engineered into *Saccharomyces cerevisiae*. Yeast is already edible and can double its biomass in 90 minutes.

5 FACTS ROLES OF DESIGNER PROBIOTICS

1 DIGESTIVE AID

The probiotic *Lactobacillus acidophilus* can be genetically modified to produce the enzyme lactase. The enzyme helps break down lactose into glucose and galactose in lactose-intolerant people.

2 ALLERGY TARGETING

When *Bifidobacterium bifidum* is edited, the probiotic makes anti-inflammatory proteins called cytokines that prevent allergic reactions.

3 IMMUNE SUPPORT

Lactobacillus rhamnosus can be genetically engineered to produce beta-defensin 2, a protective molecule that assists the body in fighting germs.

4 REDUCING INFLAMMATION

The gut microbe *Faecalibacterium prausnitzii* can be modified to increase the production of anti-inflammatory fatty acids in the gut.

5 VITAMIN PRODUCTION

When its genes are edited, *Lactobacillus reuteri* produces vitamin B12 in the gut, an essential vitamin for red blood cell production and nerve health.



© Nicholas Forder

4 METABOLIC REPROGRAMMING

The yeast has to be reprogrammed so that it can express appropriate traits from its genes.

5 INTELLIGENT BIOREACTOR

The yeast is stored in a bioreactor, which tweaks how traits such as colour and nutrients are expressed in the yeast for each food.

6 FOOD VISION

Data about the desired food is communicated to the bioreactor.

7 3D-PRINTED PRODUCT

Food compounds produced by the yeast are pumped out of the bioreactor in a liquid-like 'food ink' to be precisely printed onto a tray in the shape of well-known foods. In layers of varied composition, more complex foods can be recreated.

UNCOVERING THE SECRETS OF POMPEII

How scientists unearthed an ancient Roman city, buried by a volcanic eruption that has rippled through time

WORDS SCOTT DUTFIELD



DID YOU KNOW? Over the past 17,000 years, Mount Vesuvius has had eight major eruptions

More than 2,000 years ago, one of the most devastating volcanic eruptions ripped through Southern Italy and claimed the lives of around 16,000 people. Located on the southwest coast of Italy in the picturesque region of Campania, Pompeii was once a bustling city filled with merchants, patrons and farmers. Founded around 2,700 years ago in Southern Italy by prehistoric inhabitants called the Osci, Pompeii became a Roman colony around 80 BCE. It's estimated that around 20,000 people called Pompeii home, with a further 5,000 people residing in a popular Roman holiday town called Herculaneum just 15 miles along the coast.

Both Pompeii and Herculaneum sat in the shadow of a tall mountain we now know to be

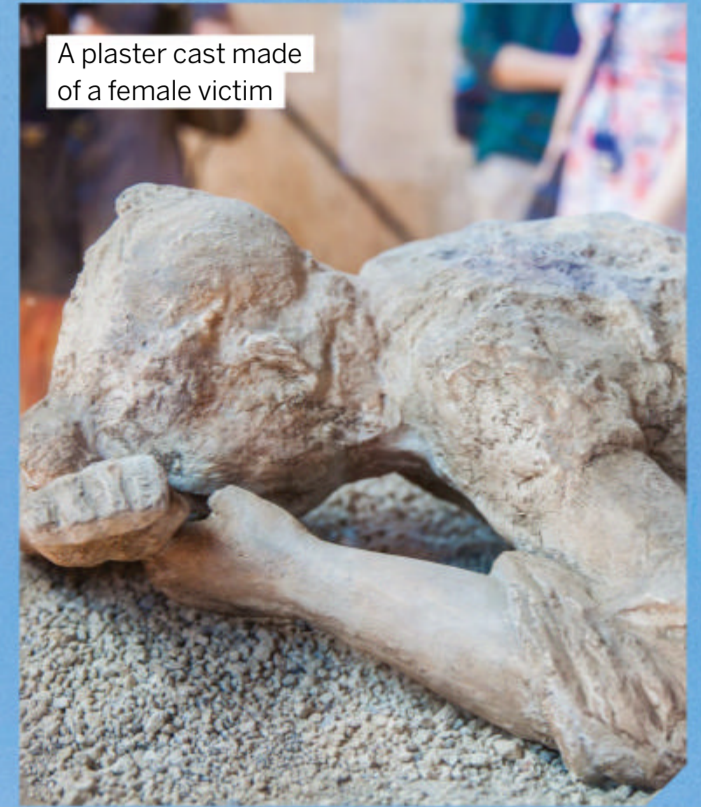
the mighty Mount Vesuvius. One autumn morning in 79 CE, Vesuvius revealed itself to be much more than a mountain and erupted in a violent explosion of hot ash and rock.

Over two days, the volcano unleashed tonnes of burning debris, known as a pyroclastic flow, engulfing Pompeii and Herculaneum. The flow was aided by south-moving winds, and by the time the volcanic event subsided, the city of Pompeii – just six miles from the volcano – was buried in a layer of volcanic rock and ash up to seven metres deep. Around 2,000 people died in Pompeii alone. It's estimated that the total number of lives lost, including those from Herculaneum and the surrounding towns and villages, was 16,000.

One of the recorded eyewitnesses of Vesuvius' violent outburst was an ancient

Did you know?

The first-ever advertisement was found at Pompeii



A plaster cast made of a female victim



INSIDE THE LOST CITY

Take a tour of some of the most important spots in Pompeii

6 FULLONICAE

There were 12 laundries in Pompeii, including the Fullonica of Stephanus, which housed a large water tank.

1 CIVIC FORUM

This was the city's hub for commerce and trade, along with the location of justice buildings and the Temple of Jupiter.

4 THERMOPOLIA

Around 80 thermopolia were placed around Pompeii: they served hot drinks and food that was kept in large jars called dolia.

3 ROMAN HOMES

Members of the upper classes resided in well-defined Roman homes with large courtyards, dining rooms, bedrooms and utility rooms.

5 BATHS

Across the city there were five public baths, not only for hygiene but for relaxation.

7 THEATRE DISTRICT

Besides the amphitheatre, shows for entertainment were held at either the 5,000-seater Large Theatre or the 1,500-seater Odeon.

lawyer and senator named Gaius Plinius Caecilius Secundus, better known as Pliny the Younger. Watching from the Bay of Naples, Pliny described the event: "It resembled a pine more than any other tree. Like a very high tree the cloud went high and expanded in different branches... sometimes white, sometimes dark and stained by the sustained sand and ashes." In recognition of Pliny's account of the event, volcanologists now classify violent volcanic eruptions as 'Plinian'.

Before Mount Vesuvius encased Pompeii in a volcanic tomb, the city had already faced a

recent natural disaster that had brought it to its knees. In 62 CE, an earthquake shook large parts of Italy, causing widespread destruction in towns that included Pompeii, Herculaneum and others around the Bay of Naples. Today, a seismic event of this magnitude would raise alarm bells that a nearby volcano might be set to blow. However, in ancient Rome the science of volcanology didn't exist, so no one understood this major warning sign. Having barely rebuilt after damage caused by the earthquake, Pompeii's people were greeted by the ferocity of Vesuvius' molten innards.

Vesuvius, first formed around 25,000 years ago, is known as a composite stratovolcano. These kinds of volcanoes are characterised by their violent eruptions, layers of ash and lava and steep slopes for lava to rush down. It sits above a subduction zone, where the African Plate converges with the Eurasian Plate. When two continental plates collide, sometimes one will dive beneath the other, which is known as a subduction zone. In this case, the African Plate is slipping beneath the Eurasian Plate, and the rock that forms the plate is superheated and compressed into magma. Magma finds its way

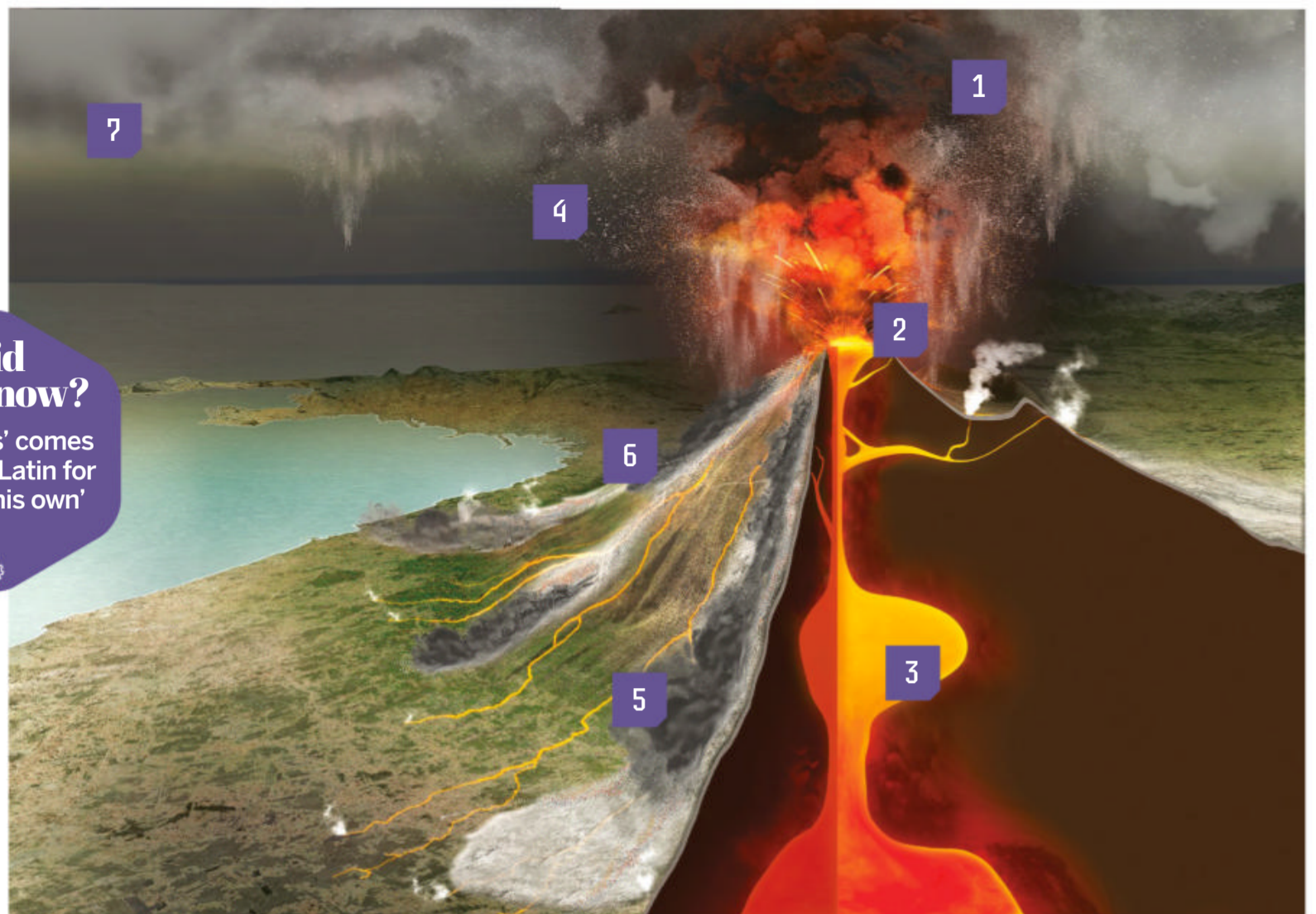
DID YOU KNOW? Vesuvius' most recent eruption occurred in 1944, destroying the village of San Sebastiano al Vesuvio

Did you know?

'Vesuvius' comes from the Latin for 'woe to his own'

2 AMPHITHEATRE

Built in 70 BCE, the enormous amphitheatre could house 20,000 people to witness battles, circus shows and animal hunting.



BURIED IN ASH

How Mount Vesuvius immolated an entire city in just 20 minutes

1 CLOUDS OF ASH

Ash clouds billowed into the air at heights of up to ten miles.

2 EXPLOSION

The explosion that wiped out Pompeii is estimated to have been 100,000 times more powerful than the Hiroshima nuclear bomb of 1945.

3 MAGMA CHAMBER

Scientists have estimated that Vesuvius contained more than a cubic mile of magma in its magma reservoir before the eruption.

4 PUMICE HAIL

Pumice stone burst from the volcano's crater and accumulated on top of the city at a rate of up to 15 centimetres an hour.

5 PYROCLASTIC FLOW

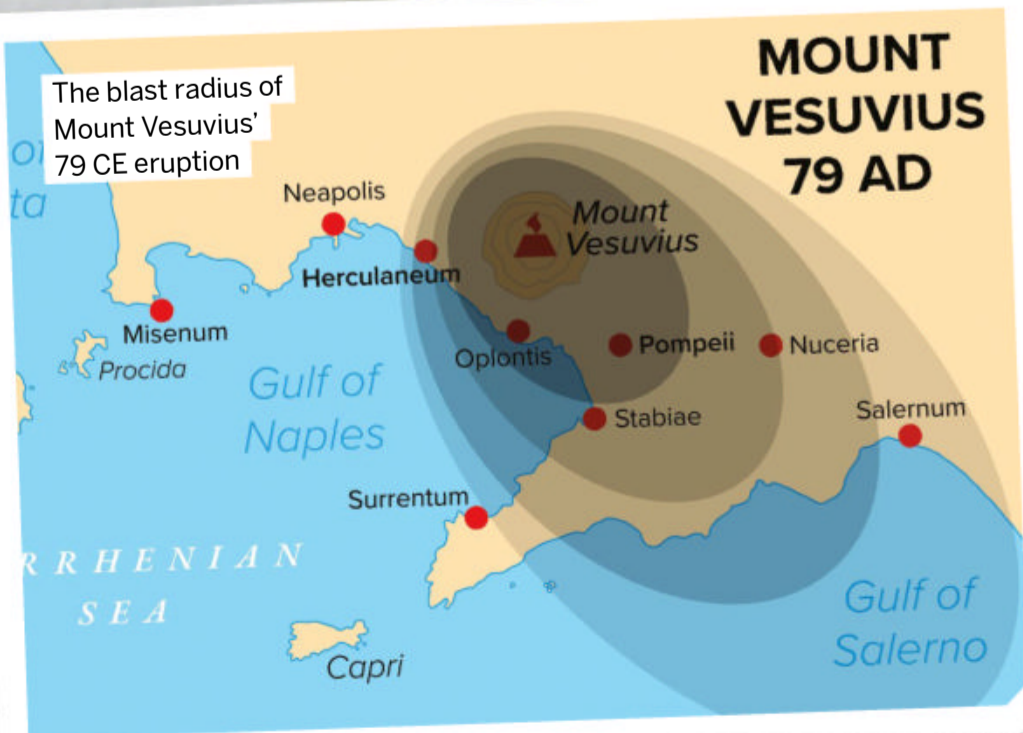
A dense cloud of hot ash, lava and gases travelled at hundreds of miles per hour towards Pompeii.

6 RED-HOT ASH

The temperature inside the pyroclastic flow would have reached up to more than 700 degrees Celsius.

7 BLACK SKIES

For around 24 hours the sky above Southern Italy was covered by Vesuvius' smoke.



“Mount Vesuvius encased Pompeii in a volcanic tomb”



THE LAST HOURS OF POMPEII

Day of the eruption, 10:00

Tremors rippled through the city, which started around four days before. However, people continued their lives as normal, unaware of what was coming.

13:00

After pressure mounted within Vesuvius, the volcano erupted in a column of ash and rock. The clouds of smoke blocked out the early afternoon Sun, plunging Pompeii into darkness.

16:00

Dark clouds moved towards the city, raining tonnes of pumice stone down on civilians. People fled to their homes for shelter, but under the weight of the stoney shower, many homes were destroyed.

Day after the eruption, 01:00

Superheated clouds of rock and ash, known as pyroclastic flows, descended the slopes of Vesuvius and engulfed the neighbouring city of Herculaneum.

04:00

The column of hot rock and ash clouds emanating from the volcano began to collapse, leading to a second pyroclastic surge.

05:00

A third pyroclastic surge reached Pompeii, but didn't completely destroy the city and its inhabitants.

07:00

The fourth and final surge completely engulfed Pompeii, and the city was lost for over 1,500 years under tonnes of pumice and ash.



A plaster cast of a Pompeii victim entering a CT scanner

to Vesuvius, along with other volcanoes on the Italian Peninsula, known as the Campanian volcanic arc, through a gap in the subducting African Plate called a 'slab window'. The escaping magma can travel up through Earth's crust and out through volcanoes.

The buried city of Pompeii was left undisturbed until the 16th century, when it was unintentionally discovered by Domenico Fontana, an Italian architect. However, it wasn't until 1709 that Herculaneum was found, and excavations at Pompeii didn't begin until 1748. Along with the forgotten roads, buildings and artwork, archaeologists discovered peculiar-shaped cavities in the volcanic rock throughout Pompeii. Researchers realised that these were impressions of the now-decayed bodies that had been encased in volcanic ash.

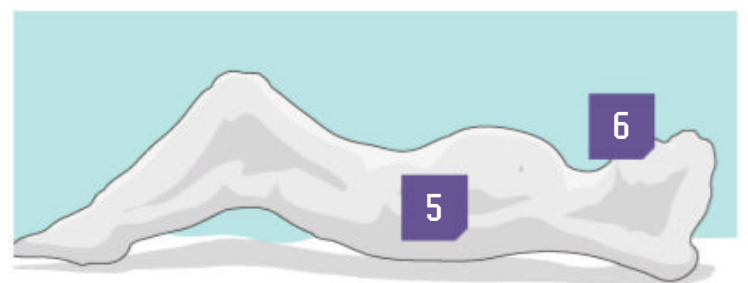
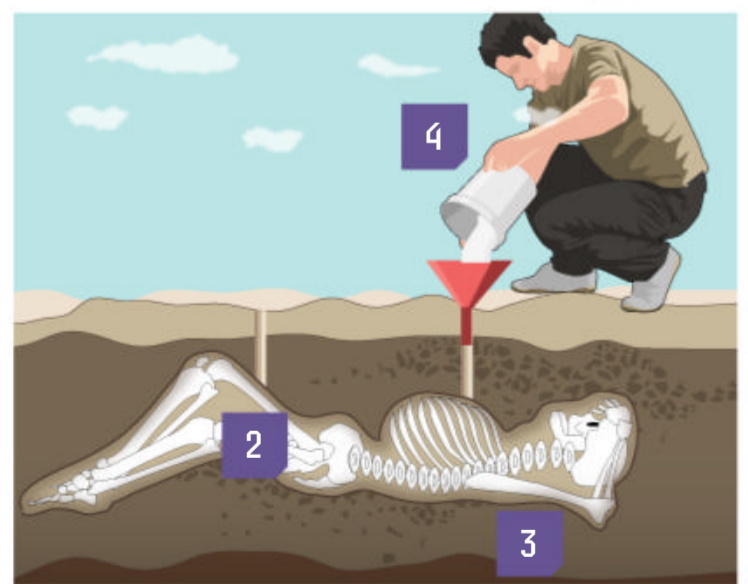
By the time the bodies had decomposed, pumice rock shells had formed around them. To preserve the form of the bodies and any remains within the cavities, in 1863 Italian archaeologist Giuseppe Fiorelli used plaster to fill the cavities, creating eerie models of the size, shape and position that a person was in when they died.

These have also been useful for modern-day scientists, who examine the contents of each cavity more closely. Since around 2000, scientists have been examining the plaster casts using computed tomography (CT) scans. In the same way that a CT machine can take a detailed image of the inside of our bodies, it can peer beneath the plaster of the Pompeii casts and image the remains within. Scans like these have helped reveal ages and genders, ancient

RESHAPING VESUVIUS' VICTIMS

How archeologists create casts of the people buried in ash

- 1 BURIAL**
The people of Pompeii were buried in a thick layer of ash and stone.
- 2 DECOMPOSITION**
Over the course of almost 2,000 years, the soft tissue of the body decayed away.
- 3 IMPRESSION**
Ash hardened around the body, and once it decayed it left behind bone and an impression.
- 4 PLASTER CASTING**
Plaster is poured into an opening, made by the archeologist, to fill the cavity and is left to harden.
- 5 CAST**
When the plaster hardens, it leaves behind a solid cast of the deceased.
- 6 CHIPPING AWAY**
The cast is broken free from the pumice shell that originally formed around the body.



DID YOU KNOW? The Herculaneum papyri were found in villa of Julius Caesar's father-in-law

diseases and the breadth of injuries victims sustained before death.

And discoveries are still being made, revealing more about life in the ancient city. In April 2024, researchers at the Pompeii Archaeological Park uncovered an ancient construction site. The site revealed how the people of Pompeii built cement walls using quicklime, pozzolanic ash and water. Artificial intelligence (AI) has also lent a helping hand in uncovering some of the secrets of ancient Rome, particularly in

Did you know?

Over 1,000 of the eruption's victims have been found

deciphering the Herculaneum papyri. In 1752, more than 1,800 charred scrolls, known collectively as the Herculaneum papyri, were discovered in a villa in Herculaneum. Although these documents survived the eruption, the texts had been completely illegible, obscured by the carbonised papyri, until now. Researchers at the University of Kentucky have used AI to decipher more than 2,000 characters.

Through a series of X-ray scans and some digital remastering, they have virtually unravelled the scrolls and trained an AI to 'read' them. The first passage of the AI-deciphered text, written by the philosopher Philodemus, discusses the relationship between an abundance of goods and pleasure: "As too in the case of food, we do not right away believe things that are scarce to be absolutely more pleasant than those which are abundant," the passage reads.



Samples of some of the Herculaneum scrolls that survived Vesuvius

ANCIENT DNA

In 2022, scientists fully sequenced the genome of a Pompeiian. The bones of a 30-year-old male and a female of around 45 were preserved in pumice following the eruption. Within the teeth and petrous bone, scientists found preserved DNA. While the female's DNA wasn't enough to sequence fully, the male's DNA revealed that he was Mediterranean and his parents were likely from Sardinia. He shared DNA with modern-day Mediterraneans who live in the south of Italy. Researchers concluded that the man was likely not part of the slave population.



DNA samples taken from the bones of Pompeii's victims can help scientists learn more about who survived

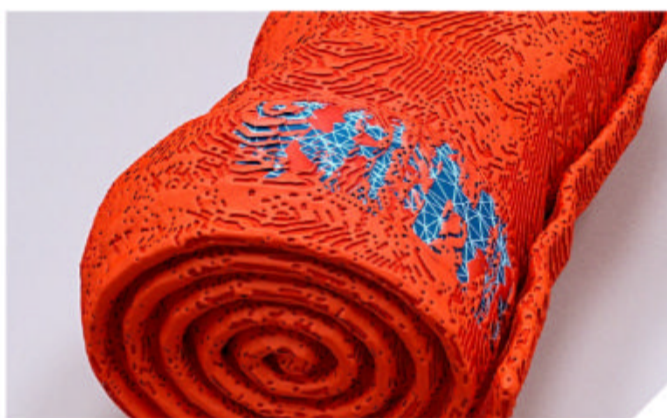
VIRTUAL UNWRAPPING

How scientists read the text on this ancient and extremely fragile carbonated scroll



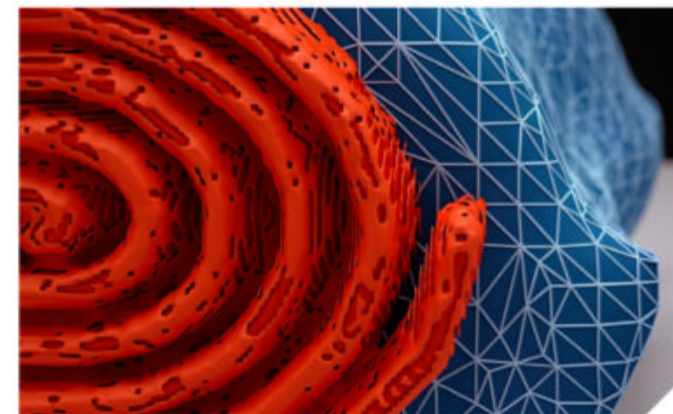
1 SCANNING

X-ray images are taken of the scroll. Through a process called tomographic reconstruction, a digital 3D model is created.



2 SEGMENTATION

The 3D image model is built using pixel cubes called 'voxels'. The voxels that make up a layer of the rolled-up scroll are isolated and termed a 'segment'.



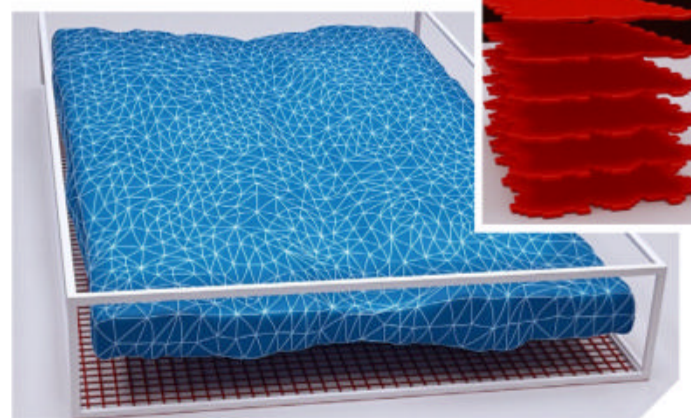
3 EXTRUDING DATA

The data collected from the segment is increased to include above and below the segment, referred to as the 'neighbourhood', to find as much ink as possible.



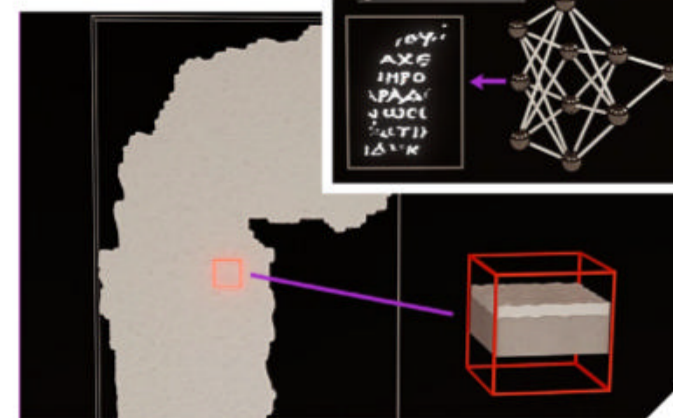
4 FLATTENING

The segment is then digitally flattened, which is known as a 'surface volume'.



5 DATA STACKING

The surface volume consists of layers of image slices that are read by the AI program.



6 READING THE WRITING

Through machine learning, the AI program can identify the thickness and density of the ink in the slices of information and produce words from the blackened papyrus.

HOW THE LORD OF THE RINGS CHANGED FICTION

The incredible history behind J. R. R. Tolkien's beloved fantasy book series

WORDS NIKOLE ROBINSON

DID YOU KNOW? A mountain range on Saturn's moon Titan is named after Mount Doom

70 years since its original publication, *The Lord of the Rings* has become one of the most celebrated stories of all time, but it was never the tale Tolkien intended to tell. He had originally put pen to paper to create a fantastical mythology for England – his life's work, which he later referred to as his *legendarium* – and Hobbits simply wandered their way into his wider world.

As early as 1914, Tolkien had begun to work on stories set in Middle-earth, but the outbreak of World War I put his writing on hold. His time as a soldier on the front lines was cut short when he was hospitalised with trench fever, though his brief experience on the battlefield would forever change him. While he recovered, he found plenty of time to write, and Middle-earth would begin to take shape across various narratives. But his work wasn't simply words – he drew maps and crafted languages, giving his world a real sense of depth and history.

In 1930, his life changed with a single sentence he wrote on the back of an exam paper: 'In a hole in the ground, there lived a Hobbit'. Tolkien, now a professor of Anglo-Saxon at Oxford, decided he better find out what Hobbits were. Whimsical stories told to his children at bedtime developed into the adventure of Bilbo Baggins, a story written separately from his *legendarium*, but taking much influence from it. The story found its way

to the publisher George Allen & Unwin through a former student of Tolkien's, and after some revisions was published in September 1937. By Christmas it had sold out.

The runaway success of *The Hobbit* prompted Tolkien's publisher to request a sequel. Tolkien took a chance on his Middle-earth mythology, now called the *Quenta Silmarillion*, but it was rejected for being too complex.

He was told that the public wanted more Hobbits, not Elven lore. After a brief bout of writer's block, he set to work on creating what would become *The Lord of the Rings*. It was a blend of his two creations – a heroic quest interlaced with hints to a deeper history. It became darker in tone, dealing with themes of war and the danger of power.

The book took 12 years to finish and several more to amend, belated by Tolkien's academic pursuits and the outbreak of World War II. It was redrafted several times – so much so that early drafts bear little resemblance to the finished work. Often mistaken as a trilogy, it was written as one epic told in six parts, but post-war paper shortages forced the story to be separated, released as three editions between 1954 and 1955. With its success, Tolkien had proven fairy tales weren't just for children, inspiring fantasy writers for generations to come and setting a high standard for world-building and epic storytelling that few have matched since.

Did you know?

Tolkien was born in South Africa in 1892



An expert world builder, Tolkien devised detailed maps of his fantasy settings

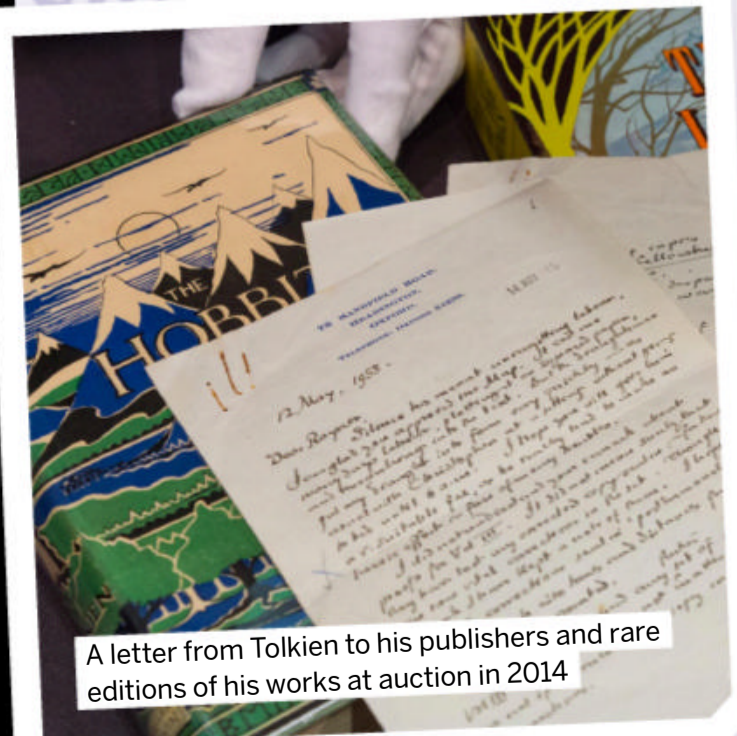


Sarehole Mill sits on the River Cole near Birmingham

MIDDLE-EARTH AND THE MIDLANDS

Growing up in the lush West Midlands countryside had a profound impact on Tolkien, who would later weave these landscapes into his works. Moving to Sarehole around the age of four, Tolkien roamed the village, its water mill and the surrounding greenery. Always nostalgic about his childhood, memories of his homestead would form the basis for Hobbiton and the Shire – even the name is borrowed from the suffixes of Worcestershire, Warwickshire and the like.

Nearby Moseley Bog is cited as his inspiration for the forests of Middle-earth, such as the Old Forest that lies just beyond the borders of the Shire, while hiking the Malvern Hills later in life gave rise to the White Mountains that divide Gondor and Rohan. In stark contrast to these places full of natural beauty, Isengard and Mordor represent the destruction of nature by urbanisation, industry and war. Tolkien mourned the loss of greenery to industrialisation, and was deeply saddened by the changes to Sarehole when he returned in 1933. This is mirrored in Frodo's return to the Shire at the end of his quest, finding his once-unspoiled home has been ravaged and defiled.



A letter from Tolkien to his publishers and rare editions of his works at auction in 2014



The Old English epic poem *Beowulf* was one of Tolkien's greatest influences

MYTH AND LEGEND

Even as a boy, Tolkien had a great love for mythology, centring his studies and eventual academic career around epic sagas in Old English, Old Norse and Celtic, among others. He lamented the fact that so little literature survived from the Anglo-Saxon period, which would become the driving force behind his own fictional retelling of British legend that would evolve into Middle-earth, borrowing from many places to fill in the blanks. Middle-earth itself comes from the Old English word *middangeard*, a translation of the Nordic word for Earth, Midgard.

While Tolkien was a student he read the Icelandic *Völsunga* saga, which features a cursed ring called the *Andvaranaut* – a possible influence for the One Ring. From the *Prose Edda* and *Poetic Edda* he took inspiration for the Dwarves, even taking some of their names from its pages. While there were Elves here, too, it's believed he was just as influenced by the *Tuatha Dé Danann* of Irish folklore, supernatural beings immune to ageing and illness who

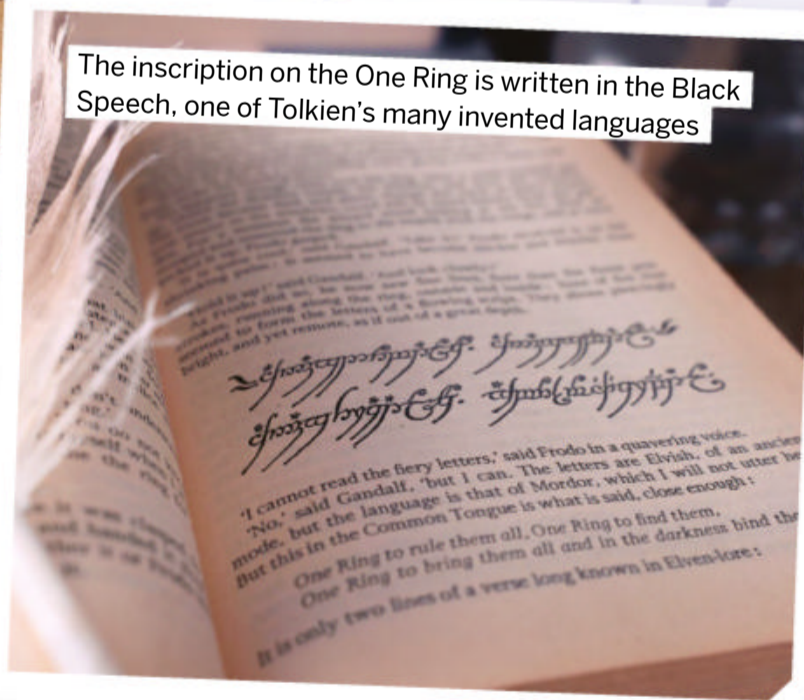
possessed magical powers. The Finnish mythological epic *Kalevala* also had a great impact on Tolkien, in particular *Kullervo*, a tale of good versus evil in the quest to claim an object of great power that may sound familiar.

One influence that cannot be overlooked is *Beowulf*, considered one of the most important works of Old English literature. Tolkien spent six years translating the poem into modern English, and gave a lecture on the epic in 1936. Devoting so much of his life to the study of *Beowulf* and its language, it's no surprise that some names, monsters and social ideas leaked into his own imagined world.

Did you know?

The first true language Tolkien invented was called *Naffarin*

The inscription on the One Ring is written in the Black Speech, one of Tolkien's many invented languages



Tolkien developing an entire linguistic evolution for them. Just as English is a Germanic language that has changed over time, his Elvish languages came from a common source, called Primitive Quendian. In crafting a broad and varied range of languages for the races and cultures of Middle-earth, Tolkien brought a depth to his legendarium that had never been seen before.



Tolkien at the launch of *The Road Goes Ever On*, which features his poetry

5 FACTS MIDDLE-EARTH PEOPLES

1 HOBBITS Averaging a metre in height, these hairy-footed humanoids live in homes built into the sides of hills. They prefer a peaceful life and eat up to seven meals a day.

2 ELVES Also called the *Quendi*, Elves are immortal – though they can die in battle. They reach maturity at around 50 years of age and do not appear to grow older after this.

3 DWARVES Tough, stocky and sporting magnificent beards, Dwarves dwell in carved-out mountains, where they expertly craft mined metals into weapons and armour.

4 ENTS Brought into being to protect the forests of Middle-earth, the 'Shepherds of the Trees' are four-metre-tall creatures with bark-like skin. The Elves taught them language.

5 ORCS The Orcs are a race of corrupted Elves that served the Dark Lord Morgoth, and later Sauron. They are brutal and aggressive, with pointy teeth and a grimy appearance.

A LOVE FOR LANGUAGE

Long before he ever thought of Hobbits, Tolkien was studying existing and ancient languages, and even constructing his own. He was a firm believer that the context of a language and the history of those who spoke it was just as important as the words themselves, rooting his invented languages in his own mythologies. In fact, Tolkien stated that he began crafting Middle-earth and its vast history so that his languages could have a home. He wrote that "the 'stories' were made rather to provide a world for the languages than the reverse. To me a name comes first, and the story follows."

Tolkien's most developed languages are those spoken by the Elves. *Quenya* has roots in Latin and Finnish – a particular favourite of Tolkien – while the more commonly spoken *Sindarin* was styled after Welsh. But these also have mythological roots, with

DID YOU KNOW? Frodo Baggins was originally called Bingo and was Bilbo's son

“The book took 12 years to finish and several more to amend”

A LIFE'S WORK

The Lord of the Rings was only part of Tolkien's tale



1 THE HOBBIT

A story Tolkien wrote for his children, he penned the first sentence while grading papers at Oxford. It was published in 1937 to great acclaim.

2 THE LORD OF THE RINGS

The success of *The Hobbit* led Tolkien's publisher to request a sequel, which later evolved into a story told across three volumes.

3 THE ADVENTURES OF TOM BOMBADIL

Published in 1962, this collection of Tolkien's

poetry included two poems about Tom Bombadil, a nature-loving inhabitant of Middle-earth.

4 THE ROAD GOES EVER ON

British composer Donald Swann worked with Tolkien to put a collection of his poetry to music, published in 1967.

5 BILBO'S LAST SONG

A poem rediscovered by Tolkien's secretary Joy Hill, he gifted it to her as thanks for her work. She ensured it was published after his passing in 1973.

6 THE SILMARILLION

Put together posthumously from Tolkien's many unpublished writings by his son, Christopher, it details the history and mythology of Arda up to the Third Age.

7 UNFINISHED TALES OF NUMENOR AND MIDDLE-EARTH

Unlike *The Silmarillion*, the works published in this book were left unedited, just as Tolkien had left them before his death.



Due to its size, *The Lord of the Rings* was split into three parts



TECHNOLOGY

HOW CLOTHES ARE MADE

These mechanical methods and material mixtures combine to form your wardrobe

WORDS AILSA HARVEY

Humans have been wearing clothes habitually for around 170,000 years. They are essential to protect the body from the elements, absorb sweat and retain heat. But in the modern world, clothes are not only admired for their functionality. Over the centuries, clothes have become increasingly focal in individuals' self-expression and identity. Studies show that wearing certain clothes or appearing well-dressed can impact a person psychologically, building their confidence and bettering their mood. For others, observing the latest fashion trends is a hobby that leaves them feeling a need to over-indulge and copy images of celebrities and models in the media.

Whether a person sources new clothes for practical or fashion purposes, each item is a result of many hours of material-sourcing, weaving, cutting and shaping. As of 2021, 65 per cent of the world's clothes were produced in China, with over 19 billion pieces of clothes being manufactured in the country. China and India are the world's leading producers of cotton, with both countries harvesting a mighty 6 million tonnes a year.

However, the mass production of clothing is taking its toll on the planet, being responsible for ten per cent of carbon emissions. If the way we produce and consume clothes continues, greenhouse gases entering the atmosphere will only increase. But by making more informed choices, we can reduce this damage to the environment. For example, it's estimated that if everyone extended the use of their clothing by nine months, the carbon, water and waste produced by the clothing industry would be 20 to 30 per cent less.

Did you know?
There are 92 million tonnes of textile waste annually

T-SHIRT TALLY

What is the production cost of one cotton t-shirt?

2,700 LITRES

It takes the same volume of water used for 50 washing machine cycles to produce one t-shirt

262%

Making a polyester t-shirt produces nearly three times the carbon of a cotton one

60°C

The temperature needed to dye a t-shirt

226 GRAMS

The cotton used for one t-shirt equals around four cotton plants

16%

Almost one-fifth of global insecticide use is for cotton farming

8,000

The number of synthetic chemicals used to turn raw materials into textiles

SEVEN KILOGRAMS

The carbon dioxide released to produce one t-shirt is equivalent to a small fire extinguisher

35 TO 50 <1%

The number of wash cycles this garment lasts

A tiny fraction of the t-shirt's total emissions come from delivering the finished product

TWO SQUARE METRES

The land needed to grow the cotton for each t-shirt

SYNTHETIC OR NATURAL

What are your clothes made of? All of your clothes contain either synthetic fibres, natural fibres or a combination of the two. Natural fibres are those that are directly derived from nature, while synthetic fibres are produced in a factory using a range of chemical compounds. Some examples of natural fibres include silk and wool from animals and linen and cotton from plants. These can be more environmentally friendly choices, as they do not contain chemicals that could harm the environment when returned to nature. Such materials are often naturally strong, such as the cellulose structure in plant fibres.

When materials are synthetically made, clothes can be mass-produced quickly and easily. The result is cheaper clothing, and specific qualities can be controlled in the production process. This includes thicker and longer fibres for multiple purposes. The downside to this type of fibre is that fossil fuels are required for their manufacturing. Oil can be refined, ultimately to turn certain petrochemicals into long chains called polymers. These are then melted and spun in a machine through small holes to make the fibres for clothes. Polyester, rayon, spandex and acrylic fibres are some examples of synthetic clothing materials.





75 million factory workers work in the fast fashion industry, and less than two per cent receive a living wage



FAST FASHION

Instead of fashion trends changing on a yearly basis, some large retailers are now mass-producing inexpensive clothing within two weeks of styles being designed. This 'fast fashion' is damaging to both people and the environment. In order to deliver cheap clothes, many companies resort to hiring people in factories to work long hours while underpaying them. And by encouraging regular changes in fashion trends, clothes are being worn for shorter periods of time, increasing textile waste entering the environment. Usually, these clothes don't last as long, as the low production costs lower the garments' quality. Due to fast fashion, the world now uses 80 billion pieces of clothing in one year – four times as many compared to just 20 years ago.

In the US, 85 per cent of textiles are sent to landfills



HOW CLOTHES DECOMPOSE

Clothes can be produced relatively quickly, but it can take around 200 years for them to decompose. The time taken for clothing fibres to disappear back into nature depends on the type of material used. Some natural fibres, like cotton, only take a few months to decompose, and the process can take around five years for wool. But synthetic fibres can exist in landfills for centuries as they are much less biodegradable. Even when clothing has decomposed, the impact of its existence isn't entirely gone. During the process of degrading, toxic chemicals and greenhouse gases are released into the earth.

COTTON TO CONSUMER

Your carefully crafted clothes undergo a lengthy process from field to fabric



DID YOU KNOW? 60 per cent of women's clothing and 75 per cent of men's contain cotton

2 SPINNING

The cotton is cleaned before being loaded into a spinning machine. This turns and twists the fibres into yarn.

2

3 WEAVING

A device called a loom is used to weave cotton together into sheets. The strands are interlaced, holding the cotton together.

3

4

4 BLEACHING AND DYEING

Heat is used to burn off surface fibres, making the cloth more uniform. Bleach is added to whiten the cotton, while other chemicals remove plant fragments. To add colour, cotton is submerged in dye, or patterns are printed on.

5 FACTS STEPS TO A SUSTAINABLE WARDROBE

1 CONSIDER YOUR NEEDS

Ask yourself if you really need an item before buying it. Fashion trends are fleeting and encourage unnecessary purchases.



2 QUALITY OVER QUANTITY

Invest in well-made clothes, which are guaranteed to last for longer periods. The less you have to buy, the less you are contributing to fast fashion.



3 SHOP SECOND-HAND

Purchasing clothes from second-hand websites and charity shops is one way to extend the life of existing clothes and prevent them from entering landfill.



4 CHECK THE LABEL

Acknowledge the materials used in each garment before buying. Opt for those with natural and recycled materials to reduce harmful waste and the need for new resources.



5 CARE AND REPAIR

Take note of labels to see how each garment needs to be washed. This will help the fibres last longer. When clothes become damaged, see if they can be salvaged and try to repair them before replacing.



Did you know?

10 to 24 rows of cotton seeds can be planted at once





Camels are also milked in some parts of the world

HOW COWS ARE MILKED

The modern-day machinery that's industrialised an ancient practice



MILK MERRY-GO-ROUND

Dairy farms have their own way of milking their cows, but many of them use rotary milking parlours. This fairground-like contraption consists of a circular platform that has been mounted on steel rollers. A cow is loaded into one of the stalls of the slowly rotating platform and hooked up to milking cups. To keep the cows still and distracted, a trough of food is placed at the head of the stall for them to eat. The platform turns, allowing more bovines to board, and milk is extracted as the cows make a full rotation of the machine before they're unplugged and released. The first 'rotolactor' was invented in 1924 and held around 50 cows. Today some rotary machines can house 100 cows at one time and allow thousands to be milked in a single day.

WORDS SCOTT DUTFIELD

An early mechanical milking machine was invented by American farmer Anna Baldwin in 1879. Baldwin's patented design used a hand-operated pump, collection pitcher and elasticated teat cup to suction out milk. Today, milking machines use a vacuum to pull the milk from the udders. Farmers attach four suction cups to the cow's udders, forming a seal around each teat. Inside the cup is a milk-collecting tube and liner. A valve connected to the device, called the pulsator, is attached to a vacuum pump and controls the pressure fluctuation inside the cup. When the vacuum pump is active during the 'milking phase', the liner moves to an open position and draws milk from the teat, which flows down the milk tube. During the 'rest phase', the vacuum is removed and the pressure in the cup returns to atmospheric levels. These phases form a 'pulsation cycle', where the ratio between time spent milking and resting in a single cycle, or 'pulse', is 60:40 at a rate of 60 pulses per minute.

Each cow in a dairy farm is milked for between five and seven minutes, two to three times a day. The yield of a typical dairy cow is around four litres of milk per day. However, during their peak lactation period, around 60 to 100 days after calving, a new mother can produce as much as 60 litres of milk per day. Cows aren't the only animals that are mechanically milked. There

are around 218 million dairy goats in the world, many of which are regularly hooked up to a milking machine for extraction. In the United Arab Emirates, camels are also attached to automated pumps to collect their milk.

"Each cow in a dairy farm is milked for between five and seven minutes"

Did you know?
There are around 270 million dairy cows worldwide



A herd of cows taking a ride around a rotary milking parlour

UDDERLY BRILLIANT

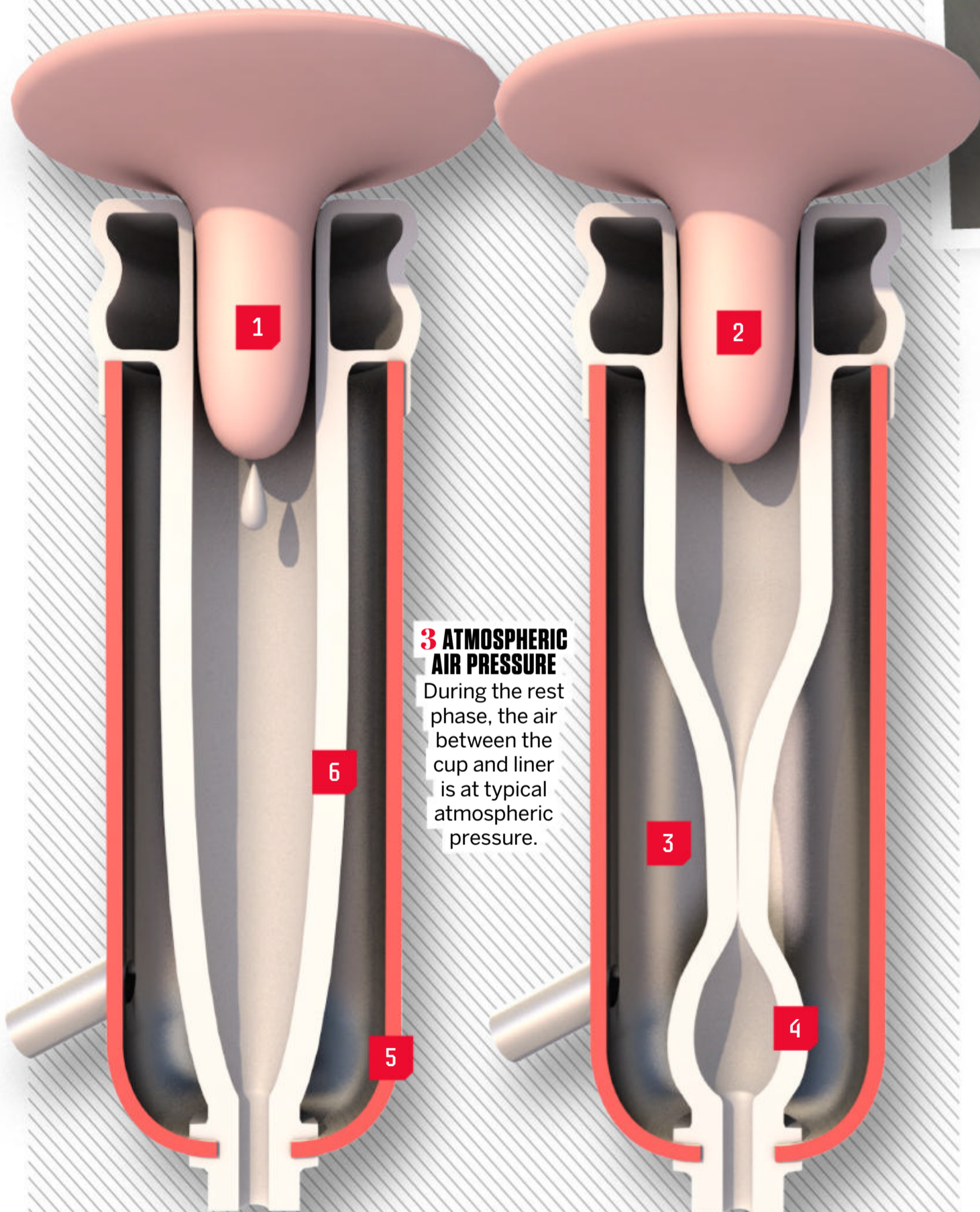
How a machine takes the manual labour out of milking

1 MILKING PHASE

Milk is extracted for around 300 milliseconds during the milking phase.

2 REST PHASE

Around 150 milliseconds are spent in the rest phase during a pulsation cycle.



3 ATMOSPHERIC AIR PRESSURE

During the rest phase, the air between the cup and liner is at typical atmospheric pressure.

6 LINER

A flexible rubber liner sits inside the cup to pull the milk from the teat with a vacuum.

5 SEAL

The teat cup creates a seal around the teat and is held on by the suction created by the vacuum pump.

4 VACUUM

The vacuum pump lowers the air pressure and pulls the liner apart, pulling milk from the teat.



ROBOTS AT THE DAIRY FARM

One in ten herds in the UK are milked using automated or robotic milking machines. Saving the hands of farmers from manually attaching milking cups, automated milking systems have been created to autonomously dock cups onto udders for milking. Once the cow steps inside a milking stall, a sensor detects an identification tag around the cow's leg. Then a robotic arm extends and attaches milking cups to each of the teats. Milk is expressed through the same pulsation phases as any manual milking machine. One of the main benefits of this method of milking is the creation of 'voluntary milking'. Through access to food, cows learn to enter the machine of their own accord and 'voluntarily' subject themselves to be milked. The identification tag allows the system to monitor stats on how much each cow supplies and can prevent over-milking.



A robotic arm automatically attaches the milking cups when the cow steps in



HOW IGLOOS ARE BUILT

These tessellated domes are designed to keep people warm, despite encasing them in snow

WORDS AILSA HARVEY

Igloos have been built by Inuit people for hundreds of years, and the fundamental design of this ancient invention is still chosen for construction in extreme environments today. The Inuit are indigenous to the Arctic and are experts at exploiting the frozen environment for survival. The word 'igloo' means 'house' in the Inuit language, Inuktitut, and is a dome made out of snow bricks. Many Inuit families used to build igloos to live in before the dawn of more permanent houses. Today, they are still used by hunters and as emergency shelters in severe weather.

The design of traditional igloos includes two layers. The elevated layer inside the igloo is ideal for sleeping, as the warmer air rises up to this level. The lower level can be used to make a fire for extra warmth and cooking, with smoke

exiting through ventilation holes. An igloo is built as a dome to reduce structural tension. It provides a more secure distribution of weight as opposed to a hemisphere, which could easily collapse as the snow compresses. Its catenary shape – the shape of the curve made by a hanging chain – has a more pointed top than a hemisphere. This gives more structural support to the igloo underneath the centre, as there are fewer horizontally placed bricks that could cause the arched top to collapse.



Igloos can be built anywhere there's snow when travelling in the Arctic

WHAT ARE THEY USED FOR?

Igloos are still culturally significant across Arctic communities and are also used by explorers and scientists carrying out temporary research in freezing environments. The densely packed blocks of snow don't just keep the bitter Arctic winds outside – they are good insulators, keeping warm air inside. As the snow is compressed into blocks, air gets trapped in pockets. This slows the warm air passing out of the igloo's walls, just as trapped air in a fleece or blanket helps keep you warm. In the future, igloos could be built in an entirely new environment: another planet.

Dome-shaped structures have been designed by NASA for potential use on Mars. To insulate the Martian igloos, ice made from water in the planet's atmosphere could fill the pockets surrounding the structures. These space igloos would let natural light shine into the space habitats.

Did you know?

Traditional igloos are lined with animal skin

Gaps are sealed with snow to give the igloo a uniform appearance

DID YOU KNOW? The most skilled igloo builders can construct one within an hour

ARCTIC ENGINEERING

How to convert a frozen landscape into shelter



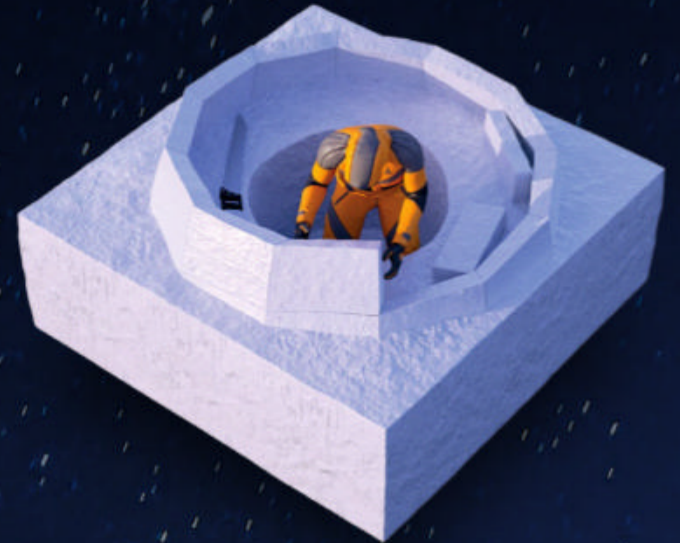
1 BRICK CUTTING

Using dense snow, cut blocks that are around one metre long, 40 centimetres wide and eight centimetres deep.



2 PLACE A PERIMETER

Make a groove in the snow around the hole you cut the blocks out of. One edge of the groove should be deeper than the other. Begin placing bricks along this groove.



3 STACK IN A SPIRAL

Continue stacking the bricks from the low end of the groove, building upwards. They should lean inwards slightly and you should pack the gaps between bricks with snow as you build.



4 CUT TWO HOLES

At least one brick should have a hole in it for ventilation. Dig a tunnel underneath one wall to be used as your igloo entrance.



5 SHAPE THE CENTRAL PIECE

When the bricks have been stacked to the top, there will be a circular gap remaining, smaller than the bricks. Shape a brick to fit this hole and secure any gaps with extra snow.



6 COMPLETE THE IGLOO

Once completed, there will be no gaps. Any cold air entering through the entrance will get trapped in the pit of the tunnel, with warm air contained in the igloo's main space.



This hotel in Kakslauttanan, Finland, consists of glass igloos. They have the classic igloo shape, but snow has been replaced with glass for permanency

MODERN SNOW HOMES

New methods and materials have been introduced in the construction of some modern igloos. Some use the same shape and design, but

with additional materials for extra insulation, such as fibreglass and foam. Others are more sizable, with complicated shapes and extra rooms, requiring support frames to hold the additional weight up for longer.

If you ever need to build shelter to protect yourself from the elements, the quicker this can be completed, the better. With new tools emerging, today's igloo builders require less physical exertion to shape snow into uniform brick shapes. For instance, moulds can be used to collect snow into even-sized bricks, while machines can cut through compressed snow with ease. Modern technology makes construction less labour intensive, but the core design of the igloo remains largely the same, reflecting the wisdom of Inuit ancestors.



This unassuming spot on Russia's Kola Peninsula is home to the world's deepest hole

CENTRAL TOWER

This 60-metre tower housed the drilling rig that was once boring through Earth's crust.



HOW THE WORLD'S DEEPEST HOLE WAS DUG

We've sent probes to the furthest corners of our Solar System, yet we've only scratched the surface of what lies beneath our feet

WORDS ALEX DALE

The Cold War took us down as well as up. In the 1960s, while the Soviet Union and the United States were embroiled in the Space Race, both countries laid out ambitious plans for an Earth science complement to their space programs: they wanted to drill through our planet's crust and find out what lies beneath.

On paper, this seemed a humble goal. At an average of 24.8 miles in depth, the rocky outermost crust is a tiny portion of our planet's 7,926-mile diameter at the equator. However, the projects were doomed to failure due to the extreme temperatures and pressures that the drill bits encountered as they ventured deeper. Despite this, the small progress made helped further our understanding of the composition of our planet by giving us the opportunity to examine the crust's structure firsthand.

The Kola Superdeep Borehole in northwest Russia began in 1970, and consisted of a central shaft with several boreholes branching off from it. One of these, SG-3, remains the deepest hole ever drilled. Just 22.9 centimetres in diameter, a specially adapted drill bit enabled drilling 7.6 miles into Earth's crust over a period of 24 years. Usually, the entire drill stem rotates, but this would have caused too much friction. A new technique was developed in which the drill bit was mounted onto a turbine, spun by pressurised mud pumped down the hole. This also pushed fragments of rock to the surface.

The findings challenged long-held scientific theories about Earth's upper layers that had been developed from surface observations



The borehole is now sealed shut, with a cap covering it

and by studying how seismic waves pass through the planet. A layer of basalt – a rock formed when lava cools – proposed to exist 3.9 miles down was absent entirely. Instead, the changes in seismic wave behaviour seen at this depth appeared to be down to changes in the granite rock caused by pressure and heat.

Water was also unexpectedly discovered at this depth, likely formed from hydrogen and oxygen atoms pushed out of the rock from the pressure. Most surprisingly, microscopic plankton fossils were discovered – surprisingly intact and estimated to be over 2 billion years old.

Drilling was abandoned in 1994 due to the intense heat, which was measured at 180 degrees Celsius at the lowest point. Coupled with a change in rock density, this made any attempts to drill further unfeasible, and so the borehole was sealed off. Drilling down to the mantle of our planet and beyond may forever prove impossible, as we'd need to invent new materials capable of withstanding the conditions.

Did you know?

The US' 'Project Mohole' preceded the Kola project

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Manta5's SL3 hydrofoil e-bike out on the water

AMAZING WATER-SKATING E-BIKE

This hydrofoil electric bike propels you over the water using motorised pedal power

WORDS SCOTT DUTFIELD

In 2017, New Zealand-based company Manta5 launched the world's first hydrofoil e-bike, called the Hydrofoiler XE-1. The watersports pioneer has since upgraded the Hydrofoiler XE-1 and launched its latest hydrofoil e-bike: the SL3. In place of a pair of wheels, the buoyant bicycle utilises a set of hydrofoil wings and an electric motor to propel you through the water.

Hydrofoils work in a similar way to the wings of an aeroplane and are designed to generate a force called lift. The wing is shaped with a curved top and flat bottom, utilising a concept in fluid dynamics called Bernoulli's principle. When water passes over the curve, it has to travel a longer distance to reach the end of the wing than it does over the flat bottom, which means that the water has to move at a faster speed over the top of the wing to meet the water moving along the

bottom. This difference in speed also creates low pressure above the wing and high pressure below it. The difference in pressure causes the wing to lift up through the water.

However, to generate lift, the hydrofoil wing needs power to propel it through the water. In the case of the SL3, this is pedal power, with some help from an electric motor that lifts the bike and keeps it mostly out of the water. Initially submerging the bike underwater and hopping aboard, the hydrofoil bike is brought back to the surface using an electrically powered motor attached to a propeller. The thrust, initially generated by the propeller, moves the hydrofoil wing and lifts the bike into the air, leaving the rear wing and steering wings underwater. Like any other hydrofoil vehicle, if the rider stops pedalling or the power cuts out, the SL3 will lower into the water until the bike's chassis starts to float on the water's surface.

Did you know?
The SL3 can ride for up to 4.5 hours on one charge

CROSSING THE COOK STRAIT

In 2021, Hayden Reeves, cyclist and head of products at Manta5, put hydrofoil biking to the test by crossing the Cook Strait, which separates the North and South Island of New Zealand. Peddling over 16 miles, Reeves crossed the Cook Strait aboard a Hydrofoiler XE-1 in two hours and 28 minutes through mostly calm waters. Reeves later said that it was only in the last four or five miles that the conditions got really bad, to the point that if the sea had been any rougher it would have been near impossible for him to ride across it.



Manta5's Hayden Reeves en route to the North Island of New Zealand on a hydrofoil e-bike

INSIDE THE SL3

The cutting-edge components that keep this high-tech hydrofoil bike above water

1 HYDROFOIL

The rear hydrofoil wing is two metres wide and made from strong carbon fibre.

2 ELECTRIC MOTOR

The propeller is powered by a 2.5 kilowatt electric motor.

1

DID YOU KNOW? Hydrofoiling was first conceptualised by Italian engineer Enrico Forlanini in 1898

6



5



3



3 CONTROLLER

Power levels are controlled from a central digital display that also shows the bike's battery life, speed and any error warnings.

6 HYDROPACK BATTERIES

The watertight removable lithium-ion batteries take two to three hours to fully charge.

8 ASSEMBLAGE

The bike breaks down into five 'sub-assemblies' for easy transport.

5 THROTTLE

Riders can push a throttle to use electrical power from the onboard battery.

7 TILT SENSORS

Sensors detect when the bike has fallen and immediately cut off power to the propellers.

4 PITCH TILTER

To steer the SL3, the front hydrofoil wing, known as the pitch tilter, is connected to a bicycle-style handlebar.

WAVE RACER

For those who want to put a bit more power behind their hydrofoil, the HydroBlade by Pelagion is the motorbike equivalent of riding the waves. Using dual eight-kilowatt electric motors, the HydroBlade can soar across the water at up to 43 miles per hour with a runtime of up to four hours. With two electrically powered propellers at the rear of the vehicle, there's only the hydrofoil wing at the front to generate lift. The HydroBlade isn't yet in production, but as of April 2024 Pelagion announced that there was "significant progress in the development of its debut product".



One of the test HydroBlades in action, zipping through the water

"The difference in pressure causes the wing to lift up through the water"





FUTURE SPACE STATIONS

As the International Space Station approaches the end of its working life, NASA is looking at what might come next

WORDS ANDREW MAY

DID YOU KNOW? The ISS has been home to more than 280 astronauts from 23 different countries

For more than 20 years, almost all crewed space missions have involved visits to the International Space Station (ISS). This is a unique resource in human history – a continuously occupied scientific research outpost in Earth orbit. The lack of perceptible gravity allows the scientists and astronauts on board to perform experiments that would be impossible on Earth, both in fundamental science and with potential applications for technology development, as well as investigating the effects of prolonged spaceflight on the human body.

The idea of an orbiting laboratory goes back to the early days of spaceflight. NASA's first space station, called Skylab, was made from the converted upper stage of a Saturn V rocket and hosted three crews between May 1973 and February 1974. During the same decade and the following one, the Soviet Union operated a series of increasingly sophisticated space stations of its own, culminating in Mir, launched on 20 February 1986. This was the world's first multi-module space station, looking rather like a scaled-down version of the ISS.

The ISS itself was born from the combination of two initially independent projects: Russia's proposed successor to Mir and NASA's plans for a similar station of its own. As well as these two former Cold War rivals, the ISS team was joined by Canada, Japan and the European Space Agency, making it a genuinely



NASA's first space station, Skylab, consisted of just one large module

Did you know?

One Soviet space station had a 'self-defence' gun



international effort. The first ISS module was launched in November 1998, and two years after that the station received its first long-duration crew members. It's been continuously occupied ever since.

Unfortunately, as with any other structure, the ISS won't last forever. Its working life has already been extended several times, but the currently planned out-of-service date of 2030 is unlikely to change, as there's no guarantee it will be safe after that. NASA is considering a possible successor, or more likely multiple successors. One follow-on that's already in the works is the Gateway space station, which NASA needs as part of its Artemis project to return humans to the Moon. This would essentially be a smaller version of the ISS, but orbiting the Moon instead of Earth. Closer to home, NASA has provided funds to a couple of private companies to explore options for next-generation Earth-orbiting space stations under an initiative known as Commercial Destinations in Low Earth Orbit.

“Unfortunately, the ISS won't last forever”

WHY REPLACE THE ISS?

The research carried out on the ISS has been so valuable – both in terms of understanding the space environment and in developing technologies that benefit us down here on Earth – that NASA wants to continue this indefinitely. But to do that, the ISS will need a replacement. The problem is that, as with an ageing car or aircraft, the ISS needs increasing maintenance just to keep it safe. The orbital environment is notoriously unforgiving, with swings of temperature over 200 degrees Celsius every time the station passes into or out of sunlight. There's also more physical damage due to ultraviolet radiation than we get at ground level, as well as constant stress from spacecraft docking and undocking. All this takes its toll on the station's structure, which will probably have to be brought back down to Earth in a controlled but fiery re-entry some time after 2030.



The ISS will eventually re-enter Earth's atmosphere like its predecessor Mir, seen here

STARLAB NANORACKS

This is one of the two projects that NASA is sponsoring. Like Orbital Reef it will be run by a team made up of several private companies, led in this case by Nanoracks – a trusted NASA supplier that has provided various pieces of hardware for the ISS. In concept, Starlab is distinctly different from Orbital Reef and the ISS, both of which require significant construction activity in space. Instead, Starlab will be assembled down here on Earth and launched into orbit in its entirety with a single flight of SpaceX's huge Starship rocket. This is analogous to the way NASA's first space station, Skylab, was launched in 1973. Another unique feature of Starlab is that it is designed to be 'free flying', rather than being locked into a fixed orbital trajectory like other space stations. It's currently scheduled for launch in 2028.

1 HABITAT MODULE

One of only two modules on this station, this is used both as living quarters and a laboratory.

2 SERVICE MODULE

This provides the station with power via solar panels, as well as containing engines for propulsion.

SpaceX's powerful Starship rocket will be used to launch Starlab into orbit

British astronaut Tim Peake doing scientific research aboard the ISS

ORBITAL REEF BLUE ORIGIN

Another project being carried forward as part of NASA's Commercial Destinations in Low Earth Orbit initiative, it's run by a consortium of private companies led by Jeff Bezos' Blue Origin, currently best known for its suborbital space tourism flights. Like the ISS, Orbital Reef will have a modular design that can be built up over time, but it's expected to have a wider range of users, including commercial companies as well as NASA. Blue Origin describes this next-generation space station as a 'mixed-use business park 250 miles above Earth'. Although its primary function will be scientific research in the same vein as the ISS, Orbital Reef will provide a much more luxurious environment, with more spacious modules, plenty of large windows and separate quarters for personal and business use. The current plan is for the first modules to be launched in 2027.

LUNAR GATEWAY NASA

While much of the excitement around NASA's Artemis program centres on its crewed landings on the Moon's surface, it has a secondary objective to set up an ISS-like space station in lunar orbit. Known as Gateway, this will be just as much an international undertaking as the ISS, with participants from Japan, Canada, Europe and the United Arab Emirates as well as NASA itself. Serving as a research laboratory and communications hub for Artemis missions, Gateway will be located in a wide elliptical orbit around the Moon. At its closest it will be just over 900 miles from the lunar surface, but as far away as 43,000 miles at its most distant. Construction activities on the first two elements of the station – one for power and propulsion and the other for habitation and logistics – are already well underway, with launch scheduled for 2027.

1 ORION CAPSULE

Astronauts will arrive at Gateway in NASA's Orion spacecraft.

DID YOU KNOW? The internal habitable volume of the ISS is comparable to that of a Boeing 747 jumbo jet

1 INITIAL CONFIGURATION

To start with, Orbital Reef will have just a few modules for research and accommodation.

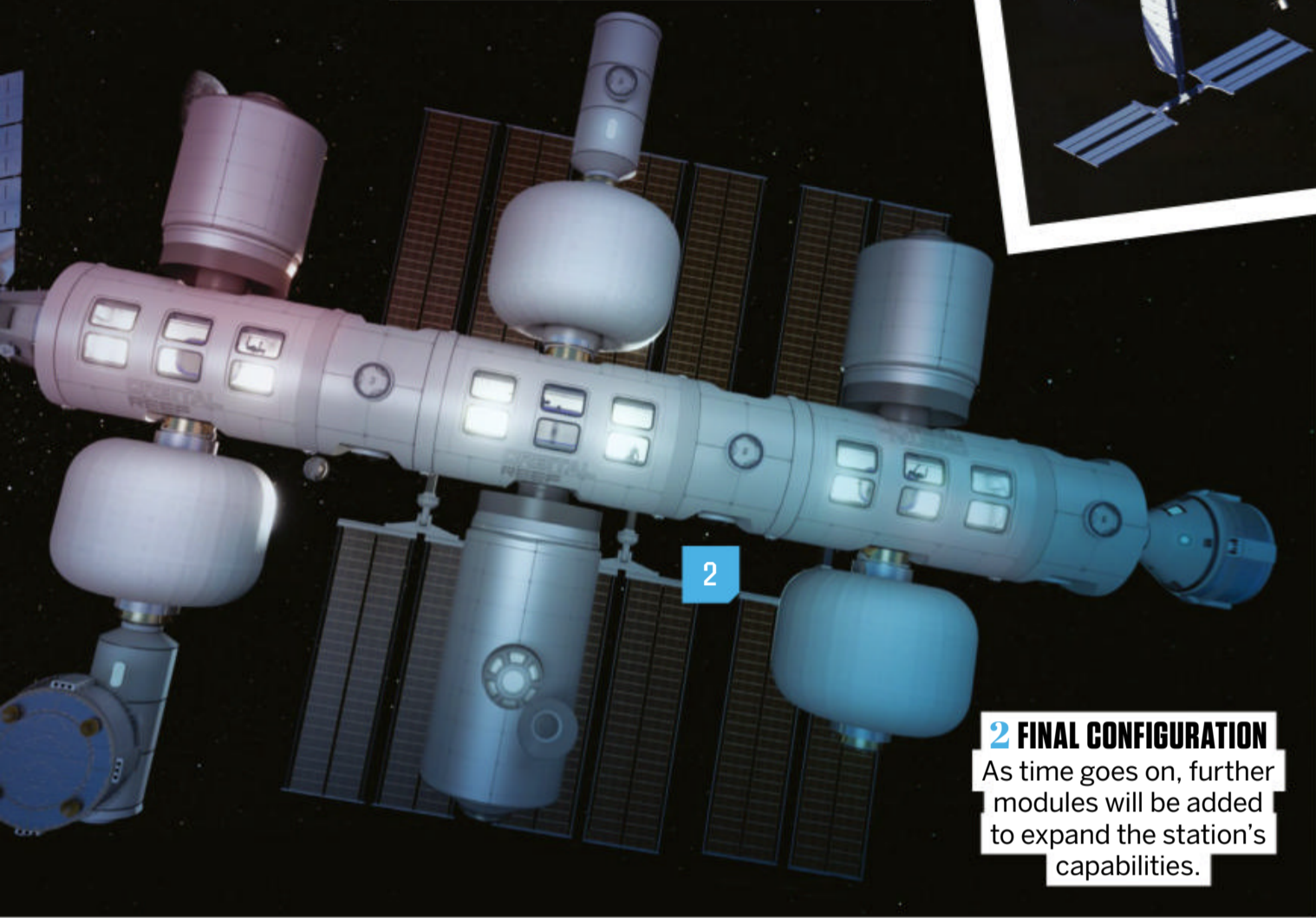
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2 FINAL CONFIGURATION

As time goes on, further modules will be added to expand the station's capabilities.



2 MODULAR DESIGN

The space station will be made up of several different modules, similar to the ISS.

2



Did you know?

Spinning a space station would simulate gravity



ISS TIMELINE

1998



The first two ISS modules, Zarya and Unity, were launched by Russia and America respectively and joined up in orbit.

2000

The ISS' first crew, two Russian cosmonauts and one NASA astronaut, took up residence for a four-month stay.

2001



The main US laboratory module, Destiny, was installed by the crew of Space Shuttle Atlantis.

2008

The European laboratory Columbus was added in February, followed by the Japanese laboratory Kibō in March.

2010



Installation of the Cupola, the ISS' panoramic Earth observation dome.

2016

A novel inflatable module, the Bigelow Expandable Activity Module, or BEAM, was added to the ISS.

2026

Private company Axiom Space is planning to add a cluster of additional modules to the ISS.

2031



The ISS will be de-orbited and deliberately crashed into a remote part of the Pacific Ocean, marking the end of decades of service.



DID YOU KNOW? Bananas are berries – fruits that develop from a single ovary – but strawberries are not

FRUIT OR VEGETABLE?

Test your botanical brain in our edible plant quiz as you explore common plant confusions

WORDS AILSA HARVEY

As some of the simplest foods in the human diet, you might assume that the difference between a fruit and a vegetable can be easily determined. However, distinctions between the two can be blurred due to two conflicting classification systems. The culinary system, which classifies foods based on their properties for cooking, is practical for producing meals, but holds discrepancies between cultures and diets.

Scientifically, the difference between the two types of food centres around the

anatomy of the plant it was sourced from. A fruit is the mature ovary of a flowering plant. Usually this is the seed-bearing part, which is responsible for reproducing more plants.

Did you know?

Figs have an equal calcium content to milk

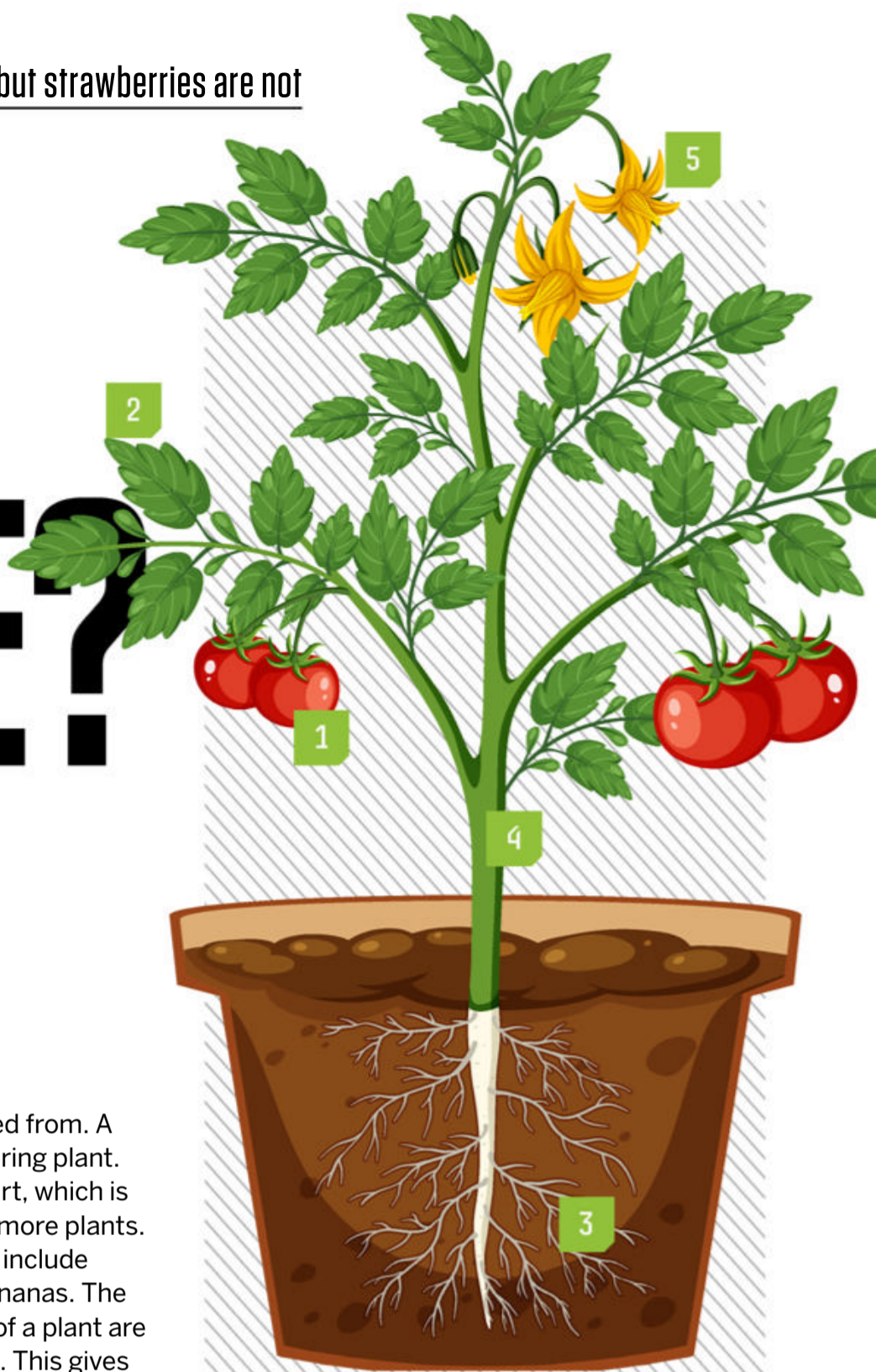
Some examples of fruits include apples, peppers and bananas. The remaining edible parts of a plant are classified as vegetables. This gives vegetables an array of appearances based on the structure of the plant they were taken from. Some are leafy greens, while others are colourful bulbs that were pulled from the ground, such as onions and leeks.

CULINARY CLASSIFICATIONS

When using foods in the kitchen, the botanical definitions are less useful to consider than the taste. This has led to culinary classifications that differ from scientific labels when it comes to grouping fruit and vegetables. Generally speaking, fruits are considered those with a sweeter or tart flavour and vegetables more savoury. A chef will consider those that can be used for desserts to be a fruit and those that make up a main meal to be vegetables.

Other properties that fall under the definition of 'vegetable' to nutritionists and chefs include tougher textures and usually a requirement to cook. Heating vegetables softens them to make them more palatable, while fruits are eaten raw. Tomatoes, which are botanical fruits, can be eaten raw but

are commonly used in savoury dishes. This is why culinary classification systems define tomatoes as vegetables.



PLANT PARTS

A plant's physiological characteristics determine its botanical classification

1 FRUIT

The tomato is the fruit of the plant – the seed-bearing structure.

2 LEAF

The leaves of many plants are edible, such as spinach, lettuce and cabbages. These are all vegetables.

3 ROOTS

Edible roots are vegetables. Some examples include turnips and beets.

4 STEM

Food that comes from the stem of a plant is a vegetable, such as asparagus.

5 FLOWER

Before turning into a fruit, flowers blossom on some plants. Edible flowers are classed as vegetables, such as cauliflower and broccoli.



TRY OUR BOTANICAL BRAIN BUSTER

Can you correctly label these produce 'fruit' or 'vegetable', according to their botanical definition?

1 CUCUMBER FRUIT VEGETABLE

2 AVOCADO FRUIT VEGETABLE

3 RHUBARB FRUIT VEGETABLE

4 OLIVE FRUIT VEGETABLE

5 SWEET POTATO FRUIT VEGETABLE

6 ORANGE FRUIT VEGETABLE

7 LETTUCE FRUIT VEGETABLE

8 CARROT FRUIT VEGETABLE

9 PUMPKIN FRUIT VEGETABLE

10 CELERY FRUIT VEGETABLE

Did you know?

Tomatoes are the most harvested fruit in the world



8

9

5

2

1

10

RESULTS

Count your correct answers to see which gardening title you earned

10

GARDEN GENIUS

You produced perfection

8-9

HORTICULTURE HERO

Blooming with knowledge

6-7

PLANT PUNDIT

Well-cultivated skills

4-5

HARVEST HOPEFUL

You're getting greener

2-3

PRODUCE PUPIL

There's room to grow

0-1

BOTANICAL BEGINNER

Grand plants start as sprouts

7

3

6

4



THE STRANGE LIFE OF A SEAHORSE

Discover the many ways that seahorses are weirder than most other fish

WORDS SCOTT DUTFIELD

Swimming around the world's oceans are curious creatures that challenge what we think of as fish. With long snouts, curved necks and curling tails, you're all but expecting them to neigh underwater. However, their equine appearance isn't the result of any genetic relation to horses. Instead, it's related to how these predators evolved as hunters. Seahorses are ambush predators, lying in wait for plankton to pass by.

To suck up swimming prey, they have evolved a long fused jaw or tubular snout. Seahorses are slow, clumsy swimmers, with only a single dorsal fin for propulsion. This means they can't chase prey and have to be just a few millimetres from them to eat. Staying still and hidden is key to their success. Their prehensile tail allows them to wrap around surrounding plant life, coral or rocks and stealthily anchor themselves in place. Their tails are also a handy tool for seahorse wrestling, where males 'fight' for female attention and territory.

But seahorse species have another unique quality: male pregnancy. Along with their seadragon cousins, seahorses are the only animals where the males look after developing embryos in a brood pouch and give birth to the resulting offspring. During mating, the female uses an egg duct called an ovipositor to offload her eggs into the pouch, which the male fertilises. Both the ovipositor and the brood pouch are positioned on the abdomen of the fish, and the two join together during mating. The male is then left to incubate the eggs before live-birthing them into the water.

Did you know?

There are 46 recognised species of seahorse

7 ADULTHOOD

If they survive, the offspring will reach maturity at around 12 months old.

3 FERTILISATION

The male releases sperm at the entrance of the brood pouch to fertilise the eggs as they move inside.

2 MOVING EGGS

During mating, the female transfers hundreds of unfertilised eggs into the male's brood pouch.

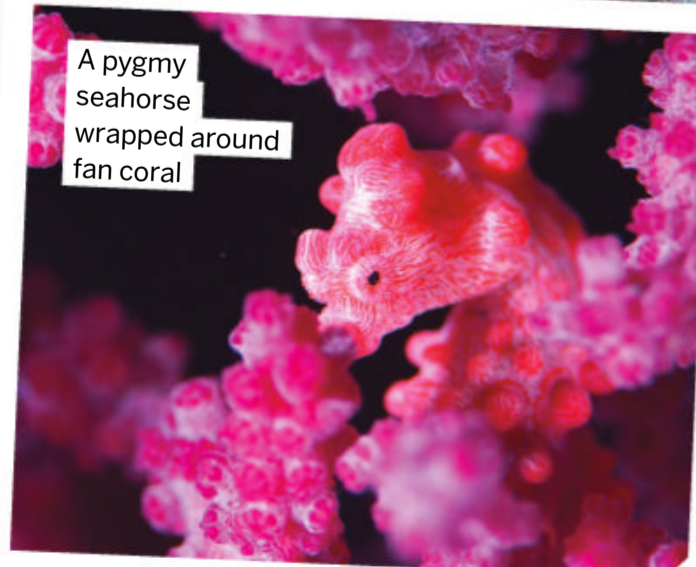
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KINGS OF CAMOUFLAGE

Without sharp fins or a venomous bite to keep them safe, seahorses rely on their appearance to survive. Like many sea creatures, such as octopuses and cuttlefish, seahorses can change the colour of their skin to blend in with the colours of their environment when under threat. Tiny pigment-filled organs called chromatophores are excited by the electrical stimulation delivered by the seahorse's nervous system. This changes the colour of their pigment and its distribution around the body. Many seahorse species have evolved to visually mimic their habitats. For example, the pygmy seahorse (*Hippocampus bargibanti*) has evolved pink lobes that imitate the structures of fan coral to seamlessly blend in.

A pygmy seahorse wrapped around fan coral



SWITCHING GENDER ROLES

Unlike the majority of fish in the ocean, it's the males that bear the brunt of childbirth

4 PREGNANT MALE

Eggs develop in the male's brood pouch for up to 30 days.

5 BIRTH

When the eggs have developed into tiny seahorses, they are ejected from the pouch and left to fend for themselves.

6

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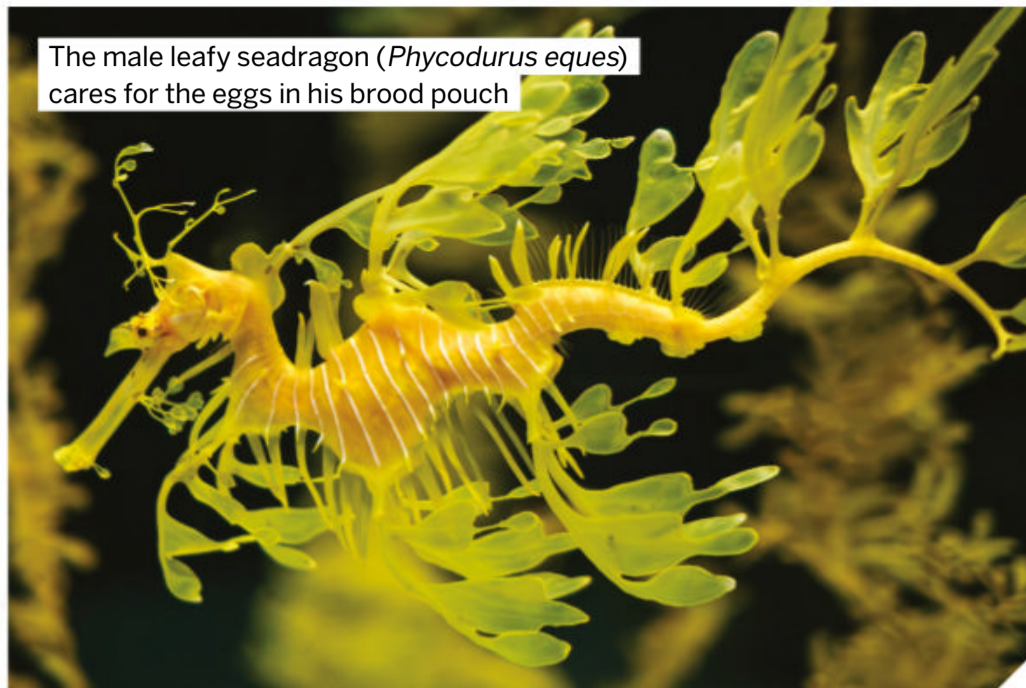
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1 COURTSHIP

A monogamous pair engage in a courtship ritual, dancing and entwining tails for several hours.

A seahorse has unique features for a fish

The male leafy seadragon (*Phycodurus eques*) cares for the eggs in his brood pouch



STOMACHLESS EATERS

A seahorse's quest for food is never over. Feasting on countless tiny fish and plankton, a seahorse spends most of its day on the hunt. In a single day, a seahorse can consume around 3,000 crustaceans, such as brine shrimp, feeding up to 50 times a day. The unsuspecting shrimp are snapped up by the seahorse's tubular feeding snout, which has no teeth, and are then sucked down through its digestive system. However, unlike many other fish, seahorses don't have a stomach. Instead, they have a single intestinal tract that ineffectively absorbs nutrients, hence their need to continually eat.



Seahorses have to get up close and personal with their prey before they can suck it up





THE HUNT

FOR

New genetic testing techniques are disproving many claims about mythical beasts. But they're also providing some intriguing discoveries...

WORDS DR DARREN NAISH

STRANGE

BEASTS



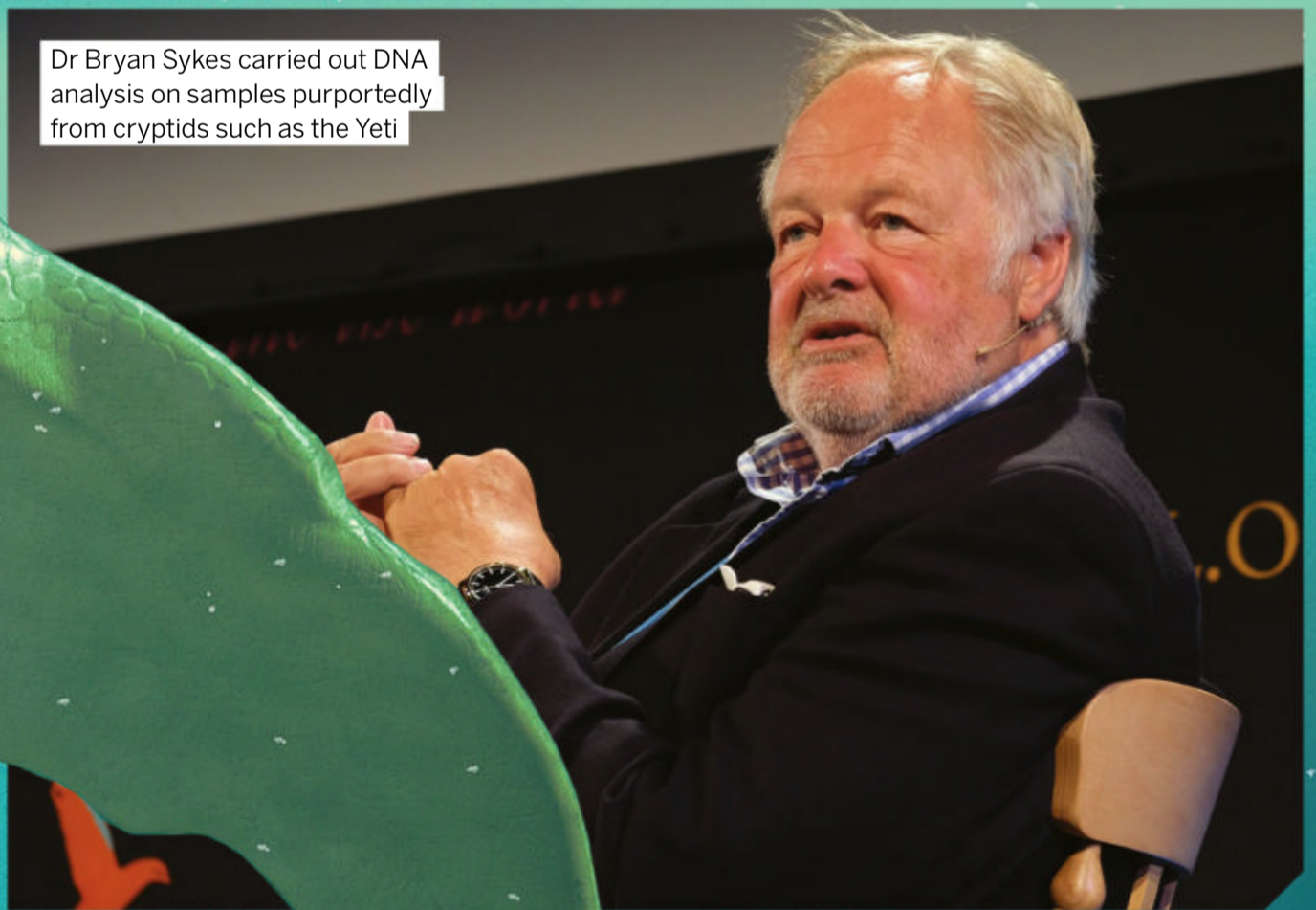
DID YOU KNOW? Some suggest Bigfoot is a relic Neanderthal, but no Neanderthal remains have been found in the Americas

A ccording to the controversial field known as cryptozoology, the world might still be full of large, strange beasts that await scientific recognition. Known as cryptids, these creatures include sea serpents, giant primates such as Bigfoot and the Yeti, and surviving dinosaurs in the Congo. While people dedicated to cryptozoology continue to collect anecdotes of these elusive beasts in the same way they have done for centuries, now is a crunch time for their field. New genetic testing techniques are allowing samples of hairs, droppings and tissues, said to be evidence of cryptids' existence, to be put to the test. Some of these genetic tests have confirmed expectations – that these creatures are

Did you know?
'Krypto' is Greek for 'hidden'

merely figments of people's imagination. But other results are truly surprising. In February 2013, a team led by Dr Melba Ketchum of Texas-based company DNA Diagnostics claimed in a paper published in the journal *DeNovo* that they had found Bigfoot DNA at numerous sites across North America. According to the team, Bigfoot is not only real, but it has a mixture of DNA from a mysterious unknown organism and modern humans. After making their announcement, the team proposed that humans and this unknown organism must have interbred about 13,000 years ago. These results were so surprising that other geneticists immediately took a close look at the team's data. They found numerous problems – the biggest being that the

Dr Bryan Sykes carried out DNA analysis on samples purportedly from cryptids such as the Yeti





MOST WANTED CRYPTIDS

Cryptozoologists advocate the existence of an extraordinary number of mystery beasts. The majority are known from a handful of anecdotes and there is no good reason to think that their discovery is likely. However, a lesser number are taken seriously by an especially large number of people – some qualified zoologists among them. These can be regarded as the ‘most wanted’ of cryptids



Brown bears interbreeding with polar bears thousands of years ago is one theory behind ‘Yeti’ DNA samples



1 ORANG PENDEK

This red or brown-haired primate is said to resemble an orangutan but have more human-like proportions. Unique to Sumatra, it’s been seen by reliable witnesses in a densely forested habitat. Some researchers have suggested a link with the supposedly extinct *Homo floresiensis*.

LIKELIHOOD OF EXISTENCE



2 THE LOCH NESS MONSTER

Reported repeatedly since the 1930s, with observations leading to theories it might be a plesiosaur, long-necked seal or giant newt.

LIKELIHOOD OF EXISTENCE



3 BIGFOOT

Also known as Sasquatch, this iconic cryptid has been reported across North America. Differences in reports have led to speculations about distinct species or subspecies. Despite a huge number of claimed sightings, all photo, trackway and DNA evidence presented so far has proved bogus or inconclusive.

LIKELIHOOD OF EXISTENCE



4 YETI

This creature of the Himalayas is reported as a giant ape. However, sightings are likely to be bears and other known mammals.

LIKELIHOOD OF EXISTENCE



5 THYLACINE

A dog-shaped marsupial with a striped back, the thylacine officially died out in 1936. However, sightings continue across Tasmania and Australia. Could Tasmanian tigers really persist in remote regions? It seems unlikely. Sightings are likely hoaxes, or mistaken glimpses of dogs or foxes.

LIKELIHOOD OF EXISTENCE



“Techniques for analysing DNA are now so honed that scientists can tell if an animal was present from environmental traces”

‘Bigfoot’ samples appear to contain a jumble of DNA from several animals, including bears, opossums and humans. They say that contamination and poor genetic sequencing best explain the results. Ketchum continues to stand by her results, but it’s safe to say that they have not exactly been accepted with open arms by other researchers.

Another study devoted to mystery primates was led by Dr Bryan Sykes, the late professor of human genetics at the University of Oxford. In 1989, Sykes and his colleagues were the first scientists to extract DNA from fossil bone – that of a Neanderthal. Curious about so-called mystery creatures, he amassed a collection of genetic samples over the years said to be from Bigfoot, the Yeti and the Bigfoot-like ‘Almasty of the Caucasus’. The results? All of the submitted Vigfoot samples were from bears, porcupines and other familiar mammals. A blow for cryptozoologists. The Almasty samples turned out to be from nothing more exotic than cows, horses and bears.

But Sykes’s results did present one surprise. Two of the Yeti samples – one from India and another from Bhutan – were from bears most closely related to ancient polar bears. Since polar bears do not inhabit those areas, the best interpretation is that a population of unusual brown bears live in the region, the descendants of an interbreeding between polar bears and brown bears that took place thousands of years ago. In short, this data seemed to show that yet-to-be-discovered bears are behind the myth, not unknown giant primates.

It’s not just genetic analysis that’s shedding new light on strange beasts that roam the countryside. Early in 2013, a team of geneticists and other scientists led by Max

Blake, then a PhD student at Aberystwyth University in Wales, set about studying a lynx specimen from 1903 that formed part of the collection at Bristol Museum and Art Gallery.

People have been saying for decades that exotic cats might be lurking in the British countryside. In fact, these sightings have been a constant presence since at least the early 1900s. The hypothesis favoured by some is that exotic cat species have escaped from private and public collections – circuses, menageries and zoos – resulting in the countryside being constantly restocked with these animals. So could the 1903 lynx specimen shed light on this idea?

Blake and his fellow researchers took hair and bone samples from the lynx. Attempts to extract DNA at Durham University's Ancient DNA Laboratory proved completely fruitless, presumably because the specimen had, in the intervening 110 years, been treated with

chemicals that had broken down its DNA. But traces of the radioactive element strontium extracted from the cat's bones proved to be more insightful, showing it had spent most of its life in either Canada or the Dartmoor region in Devon. One form, or 'isotope', of strontium, strontium-87, varies in its proportions relative to a more stable form, strontium-86, according to the chemistry and age of the rocks in a location. It means that these ratios – absorbed by an animal's tissues during its life – provide a strong indication of where the creature spent most of its life.

But the analysis didn't end there. Close inspection of its teeth revealed a buildup of hard plaque, more typical of an animal that had spent most of its lifetime in captivity. Meanwhile, an analysis of the dimensions of its skull helped show what species of lynx it was. The conclusion? It was a recently escaped lynx – most likely a Canada lynx – that had been in

Did you know?

Scientists estimate that 86 per cent of species are undiscovered



Research shows that the 1903 lynx specimen was a Canada lynx that escaped from captivity

THE DNA DATABASE THAT HELPS RESEARCH

Sequencing DNA from hairs, feathers, skin and bones is now vital to determining whether a sample belongs to an as-yet-discovered mythical beast. And this research has been made easier by GenBank, a gigantic online resource of genetic data. Initiated in 1982, it currently contains the genetic codes of more than 300,000 organisms – ideal for checking samples found in the field. Its use will continue to grow, as the database doubles in size every 18 months.



New DNA is being tested and added to the database all the time

DISCOVERED BEASTS

Even today, new animals are still being confirmed



SAOLA

A large, hooved mammal related to cattle was discovered in Vietnam in 1992. It's one of the largest land mammals found in recent years. Although it's often stated as an example of how new large animals can still be found, it was not reported anecdotally prior to its discovery.



OKAPI

A forest-dwelling member of the giraffe family was discovered by Sir Harry Johnston in 1901 following his search for the atti, a 'forest donkey' reported by Henry Morton Stanley in 1887. The discovery of the okapi has often been hailed as the ultimate cryptozoological success story.



KIPUNJI

A shaggy-furred, tree-dwelling Tanzanian monkey named in 2005. What makes it of special interest to cryptozoologists is that it was only discovered after conservationist Tim Davenport investigated rumours of a shy, unusual species known to local people.



captivity for most of its life. In other words, the research supports the idea that exotic cats do roam the countryside and are escapees from captivity – and that they have been doing so in Britain since the early 1900s.

The future is likely to hold more insights into mythical creatures. Techniques for extracting and identifying DNA have now been honed to such a degree that scientists can determine whether an animal was present simply from the traces it leaves in its environment – a few droppings, or even saliva and skin cells, are sufficient. In this 'sight-unseen' detection method, a small quantity of soil or water is collected from the habitat suspected to be occupied by a target animal. It's then analysed in laboratories, looking for traces of environmental DNA (eDNA).

In 2012, analysis of eDNA in half a litre of seawater collected off the coast of Denmark revealed the presence of 15 fish species – including a few rare vagrants. The DNA traces most likely came from skin and scales, mucus and gut cells in faeces. In the same year, an analysis of another sample of seawater collected from the Baltic Sea found eDNA from long-finned pilot whales, a species reported occasionally in the region but generally thought to be an extremely rare visitor.



Environmental DNA from long-finned pilot whales has been found in the Baltic Sea

The very idea that people might search for these tiny traces of environmental DNA is new, and its potential for cryptozoology can't be underestimated. It might show us that a species once considered extinct is actually alive and well, or provide evidence that previously unknown species exist. Either way, the future of this research is going to be very interesting.

ARE CRYPTIDS JUST A LEGEND?

These strange beasts may just be ideas handed down through generations. Folklorists and sceptics argue that cryptids are products of tradition and psychology – they are ideas or stories that get passed through generations. Modern ideas about lake or sea monsters, for example, evolved from myths when far less was known about the world. This was explored by Michel Meurger and Claude Gagnon in their book *Lake Monster Traditions: A Cross-cultural Analysis*. Lake monsters, they argued, are linked to beliefs that lakes are bottomless and do not give up their dead. These have only recently been interpreted as descriptions of real monsters.

UNEXPLORED REGIONS AROUND THE WORLD

Where are we most likely to make new discoveries of animals?

1 MARIANA TRENCH

Located in the Western Pacific, this is the deepest part of the world's oceans and is little explored. The chances are high that large animals, including new sharks, fish and squid, await discovery here and in other deep-sea locations.

2 VENEZUELA

The Sierra de Maigualida region has been described as 'almost unexplored'. Clothed in forest, it has yielded a large number of peculiar, unique plants in recent years. New animals are almost certainly inhabiting the region.

4 SOUTHEAST ASIA

This remains a hotspot for the discovery of large mammals and other animals, with the forested, often mountainous regions of Vietnam, Laos and Indonesia remaining poorly known. New hoofed mammal species have been discovered here since the 1990s.

3 ANTARCTIC

The interior is generally only surveyed by aircraft, and ice-free valleys, mountain ranges and giant lakes add complexity to this gigantic continent. While it is unlikely that large animals await discovery, it's highly plausible that smaller animals have yet to be found here.





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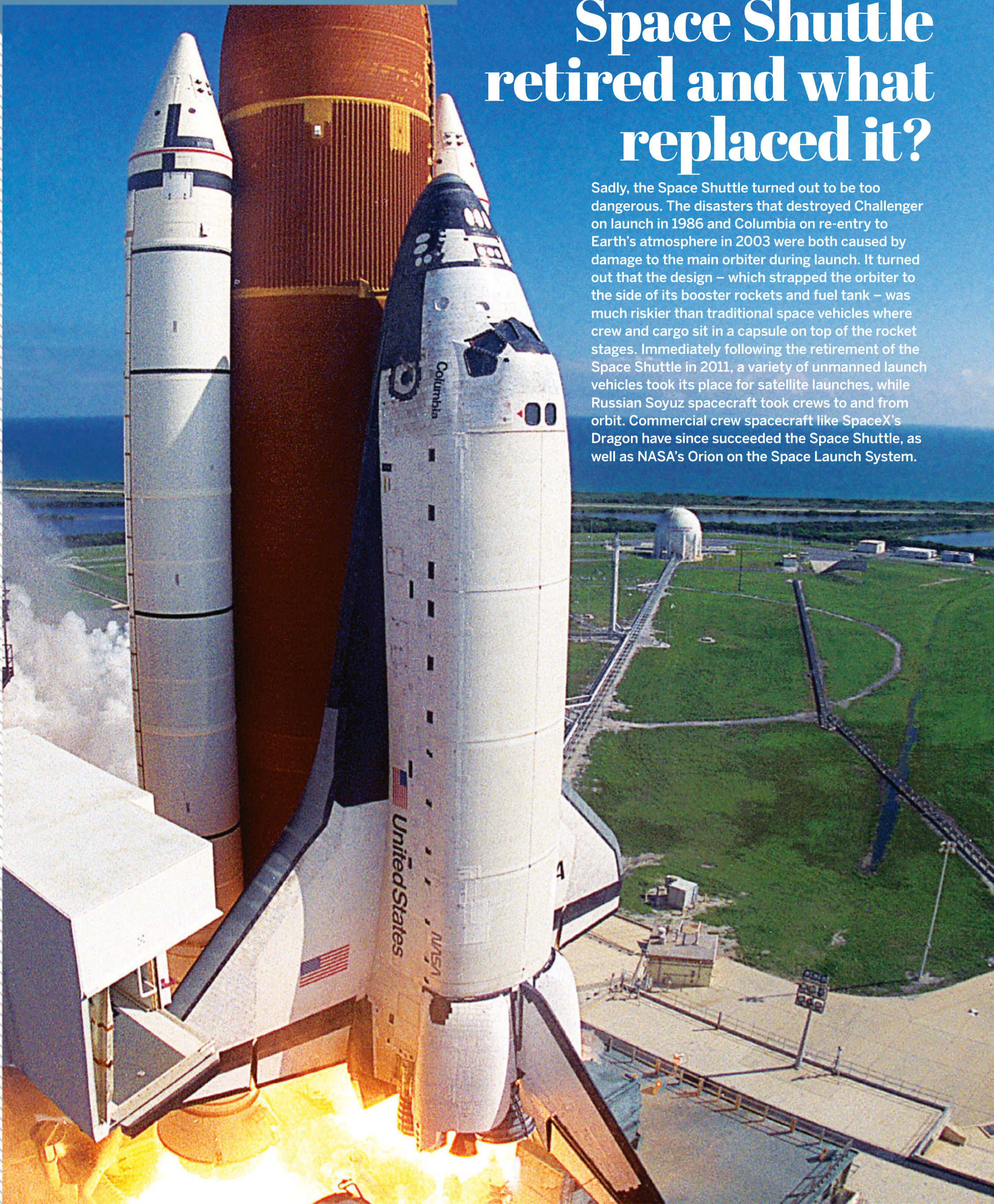
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BRAINDUMP

Amazing answers to your curious questions

Why was the Space Shuttle retired and what replaced it?

Sadly, the Space Shuttle turned out to be too dangerous. The disasters that destroyed Challenger on launch in 1986 and Columbia on re-entry to Earth's atmosphere in 2003 were both caused by damage to the main orbiter during launch. It turned out that the design – which strapped the orbiter to the side of its booster rockets and fuel tank – was much riskier than traditional space vehicles where crew and cargo sit in a capsule on top of the rocket stages. Immediately following the retirement of the Space Shuttle in 2011, a variety of unmanned launch vehicles took its place for satellite launches, while Russian Soyuz spacecraft took crews to and from orbit. Commercial crew spacecraft like SpaceX's Dragon have since succeeded the Space Shuttle, as well as NASA's Orion on the Space Launch System.





IF THERE'S THE SAME AMOUNT OF IRON IN OUR BLOOD AS IN A SIX-INCH NAIL, WHY DON'T WE ATTRACT MAGNETS?

Iron and other ferromagnetic materials – those that are naturally drawn to a magnet – are themselves made up of lots of tiny magnets. Put a chunk of iron next to a permanent magnet and these tiny magnets all line up in parallel. This allows the iron to produce its own magnetic field and attract the permanent magnet. For this to happen, a substantial number of iron atoms need to be in close enough contact to interact with one another. Most of the four grams or so of iron that can be found inside the average human body is bound up inside haemoglobin – the red-coloured protein in our blood which is responsible for carrying oxygen. Fortunately, as a result the iron atoms are not concentrated enough to join forces to generate their own magnetic field and attract nearby magnets.

WHAT EXACTLY IS DARK MATTER?

By measuring the motion of stars in our galaxy and others, astronomers can tell that galaxies in general contain much more mass than can be accounted for by their visible stars, gas and dust. In fact, normal, or baryonic matter – essentially anything with protons and neutrons – seems to account for just 15 per cent of all the mass in the universe. The rest is

composed of something else... something that's not just dark, but entirely transparent and unaffected by any kind of radiation. Dark matter plays an important role in the structure of the cosmos, too. Its enormous gravity causes baryonic matter to cluster around it, coalescing into galaxies and galaxy clusters. As a result, its distribution is similar to that of visible objects.

As for what exactly it is, current research points to some kind of undiscovered heavyweight particle that's capable of passing through baryonic matter as if it weren't there. Astronomers and physicists have made attempts to detect these weakly interacting massive particles, or WIMPs, and measure their properties, but so far they've eluded them.

HOW DO STINGRAYS EAT?

Stingrays, like other members of the ray family, are bottom feeders. They are related to sharks but they don't have sharp teeth. Depending on the species, they may either have two hard plates for crushing shellfish or just sucking mouthparts. Stingrays mainly eat molluscs and crustaceans, but because their eyes are right on the top of their heads they can't see their prey, so they use their sense of smell and the electric field sense common to all sharks. The venomous sting at the end of the tail isn't used to catch food – it is purely for self-defence.



Who were the Templars?



The order of the Knights Templar was a small contingent of warrior monks who defended Christian pilgrimage sites in the Holy Land in the Middle Ages. Christian Crusaders took Jerusalem in 1099, but struggled to maintain control of venerated holy sites tied to the birth, life and crucifixion of Jesus. In 1119, two French knights swore to defend these sites from 'infidels' and protect Christian pilgrims. They amassed a small band of compatriots and were given shelter in the Al-Aqsa Mosque, which is believed to be the

ancient site of King Solomon's Temple. In 1129, the Knights Templar took monastic vows of chastity and poverty. Soon they received recognition and financial support from the Vatican, and were given land by kings and lords throughout Europe. Christians were expelled from the Holy Land in 1291, and the Knights Templar never recovered. The grand master, Jacques de Molay, was arrested in 1307 and accused of heresy, sodomy and idol worship. Although the charges were almost certainly false, the leader of the Templars was burned at the stake.

Why does lava glow red?

Simply put, because it's hot – in fact, lava can reach up to 1,250 degrees Celsius. Heat excites atoms, which can boost atoms' electrons to higher orbitals. When an excited electron returns to its normal orbital, it releases its excess energy as a light photon. Collectively, these photons produce a glow. The colour varies between atoms of different elements. And why is lava so hot? Lava is molten rock that escapes from Earth's inner mantle layer. Scientists trace the mantle's heat back to the planet's formation. The immense energy of material accreting together to form the Earth heated the planet's interior, and the outer crust has bottled it up all this time.

HOW LONG CAN MODERN SUBMARINES REMAIN UNDERWATER WITHOUT HAVING TO SURFACE?

Thanks to their state-of-the-art built-in reactors, modern nuclear submarines never have to surface to refuel. When the submarine goes into service, it has all the nuclear fuel it will need for its projected lifetime, which can extend as long as 33 years. Just as in a nuclear power plant on land, nuclear fission in the reactor generates heat, which produces steam, turning a turbine and providing electricity. The reactor makes the submarine completely self-sufficient, with enough juice to keep all the equipment running day in, day out.

Modern submarines don't need to come up for air, either. Chemical processes continually remove carbon

dioxide from the air on board, while oxygen generators use electrolysis to extract oxygen from the surrounding seawater. As long as the equipment is working properly, the air is always fresh and breathable. Similarly, on-board distillation plants continually turn seawater into clean drinking water.

In fact, the only limiting factor for staying submerged is the food supply. Submarines typically carry about 90 days worth of food, which is kept in storerooms, refrigerated rooms and freezers. For exceptionally long missions, when the storerooms fill up, submarine crews may have to stack canned goods along floors and passageways as well.



What is Venus' atmosphere made of?

Venus might be named after the goddess of beauty, but in reality it's a hellish planet of scalding temperatures and crushing pressures, largely as a result of an atmosphere that's mainly made up of toxic, choking carbon dioxide. This heavy gas comprises 96.5 per cent of the Venusian atmosphere, with nitrogen accounting for most of the remaining 3.5 per cent and other gases reduced to tiny traces. Just like on Earth, where it only accounts for 0.04 per cent of the atmosphere, carbon dioxide acts as a powerful greenhouse gas, trapping heat near the surface of Venus and creating searing temperatures of around 470 degrees Celsius. As if that wasn't bad enough, the brilliant clouds that make Venus look so beautiful are actually made of corrosive sulphuric acid.



WHY DO WE EAT CHOCOLATE EGGS AT EASTER?

Eggs are a potent symbol of life, renewal and rebirth dating back millennia. The egg was adopted by early Christians as a symbol of the resurrection of Jesus Christ on Easter. The hard shell of the egg represents the tomb and the emerging chick represents Jesus, whose resurrection conquered death. The tradition of eating eggs on Easter is tied to Lent, the six-week period before Easter during which Christians traditionally abstained from all animal products, including meat, dairy and eggs. Since chickens continued to lay eggs throughout Lent, people would hard boil the eggs, decorate them and save them for Easter. The modern tradition of eating chocolate eggs at Easter is a fun, kid-friendly twist on this ancient religious ritual, which originated in Europe during the early 19th century.

WHY ARE SMOOTHIES WORSE FOR US THAN JUST EATING RAW FRUIT?

Smoothies are hugely popular as a healthy, calorie-conscious snack that fills you up without fattening you up. But not all smoothies are created equal. The worst include ingredients like full-fat ice cream, peanut butter and chocolate and pack over 1,000 calories – more than an entire fast-food meal. The best smoothies contain a serving of whole fruit, low-fat dairy protein and a natural sweetener like honey or agave nectar, which has a low glycaemic index (GI). Raw fruit is the ideal snack for a quick burst of natural energy and some extra fibre. But if you want to stave off hunger for several hours, it's best to make your own healthy smoothie from scratch at home using fresh ingredients.

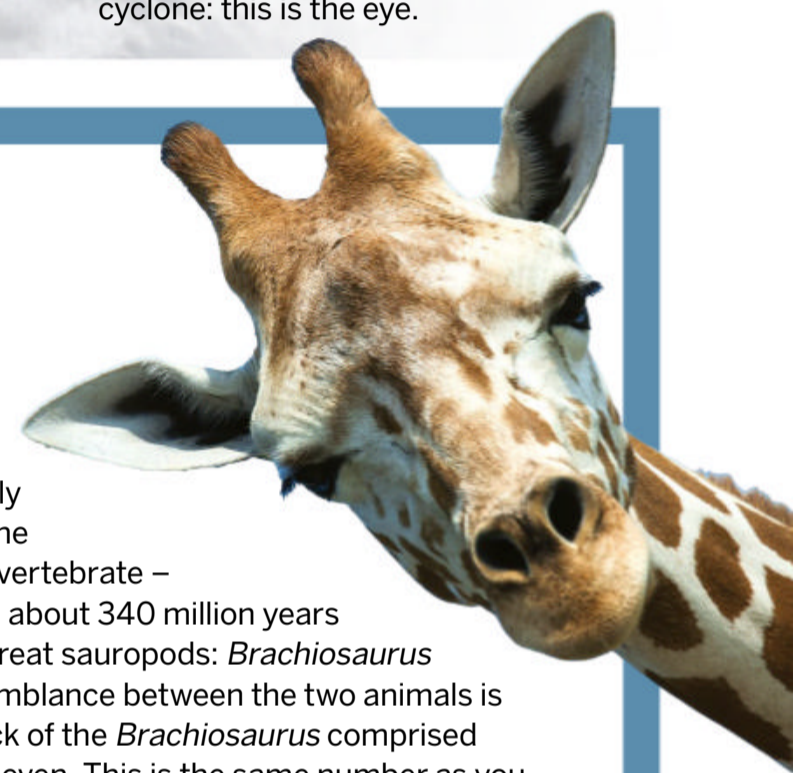


WHAT BRINGS ABOUT THE EYE OF A STORM?

An eye is a characteristic feature of tropical cyclones, which are also known as hurricanes and typhoons in other parts of the world. Near the equator, warm ocean water can heat the air immediately above it, causing it to rise. As the warm, moist air rises, the air pressure below drops and surrounding cooler air rushes in. This air then heats up over the warm water and lifts as well. As the air rises, it cools, forming clouds and storms. Because of Earth's rotation, the surrounding air rushes in with a swirling motion, causing the entire storm system to spin. As it rotates faster, some air at the top of the system sinks through the centre of the storm, forming a relatively calm, low-pressure area at the heart of the cyclone: this is the eye.

ARE GIRAFFES DESCENDANTS OF BRACHIOSAURUS?

No. *Brachiosaurus* was a dinosaur that lived around 150 million years ago. By the time *Brachiosaurus* became extinct, there were already early mammals called Eutheria living alongside the dinosaurs. The Eutheria gave rise to the placental mammals, then the Artiodactyla and eventually the modern giraffe. The most recent common ancestor of the *Brachiosaurus* and the giraffe would have been an amniote vertebrate – somewhere between a reptile and an amphibian – that lived about 340 million years ago. Confusion might arise from the name of one of these great sauropods: *Brachiosaurus giraffatitan*. This means 'giant giraffe', but the physical resemblance between the two animals is superficial. They're both large quadrupeds, but the long neck of the *Brachiosaurus* comprised dozens of separate vertebrae, whereas the giraffe has just seven. This is the same number as you have in your neck – it's just that the giraffe vertebrae are each a lot longer.



Why does welding cause sparks?



Welding involves heating two pieces of metal or plastic so that they melt and fuse together, resulting in a very strong seam. This requires temperatures of around 5,500 degrees Celsius, which are most commonly generated with an electric arc. An arc is a discharge of electrical current – just like a tiny lightning bolt. In arc welding, the parts to be welded are connected to a grounded wire, and an electrode made of filler metal is connected

to the power supply. When the electrode is put into contact with the welding materials then moved away, the air between the two is ionised and electrons leap across the gap. This generates bright light and intense heat. As the arc is drawn along the join, both the tip of the electrode and the working materials become liquid and fuse together. At such high temperatures, the molten metal bubbles and spits, expelling a shower of sparks.

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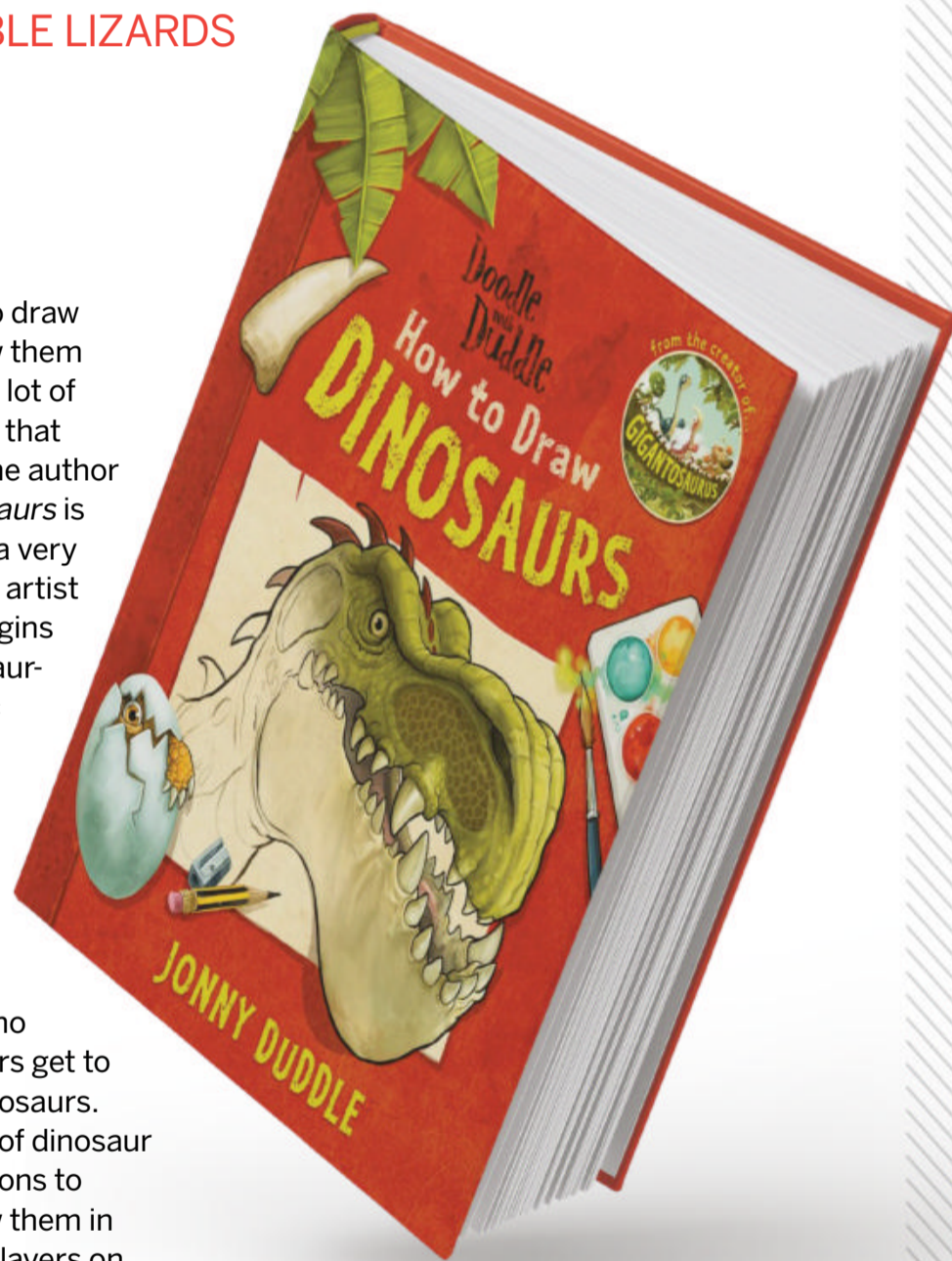
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Would you like to be able to draw cartoon dinosaurs? Draw them really well? If you put in a lot of practise with the lessons that Jonny Duddle teaches, you could. The author and illustrator of *How to Draw Dinosaurs* is a self-proclaimed 'doodler', which is a very modest way of saying he's a cartoon artist – a very good one at that. Duddle begins to take the reader through his dinosaur-drawing methods by listing the basic equipment – just a pencil to start – although he does have his favourite tools of the trade that include a sketchbook and a biro, which isn't an advisable drawing implement for mistake-prone beginners. He introduces us to a quartet of his own made-up dinosaur-like characters who assist in the lessons, and then readers get to start drawing some (mostly) real dinosaurs.

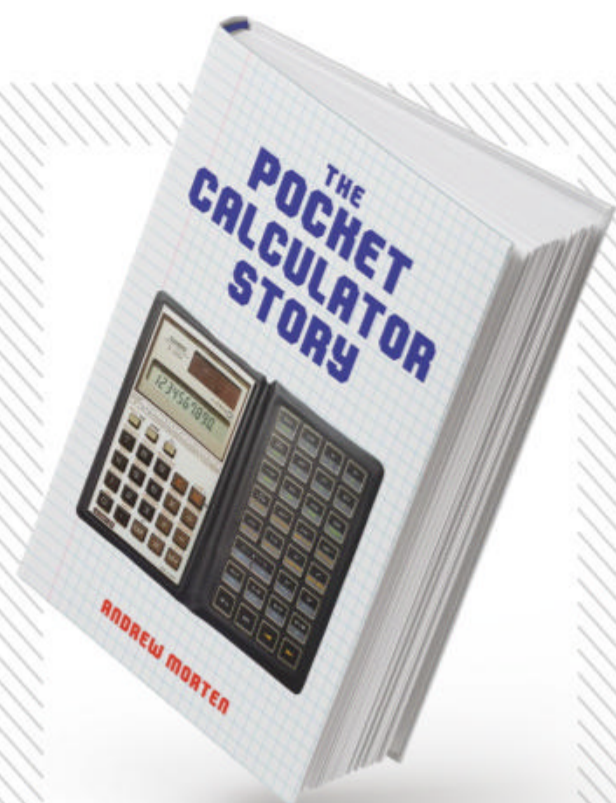
Duddle alternates between pages of dinosaur facts with finished dinosaur illustrations to step-by-step lessons on how to draw them in his style: it's often a case of building layers on top of a basic shape – such as the ellipse that forms the body of a diplodocus... readers of a certain age may recall Tony Hart turning amorphous blobs into striking works of art with a few simple strokes.

Dinosaur skeletons, which follows a step-by-step illustration on how fossils form, is a particularly vibrant section that gives a budding artist a sense of the internal structure of a dinosaur and some shapes that they could begin to build their own dinosaur drawings around. Finally, for those who have advanced in their dino-doodling and have the confidence to go it alone, there's space in the back of the book to draw their own fantasy dinosaur and a comic strip of their own doodles.



“It's often a case of building layers on top of a basic shape”

But even if the reader has no interest in trying any of Jonny Duddle's drawing lessons for themselves, *Doodle with Duddle: How to Draw Dinosaurs* is a fun read for school-aged students, accompanied by captivating cartoon dinosaurs. At the very least, it's a good drawing reference for a future school dinosaur project or art homework.



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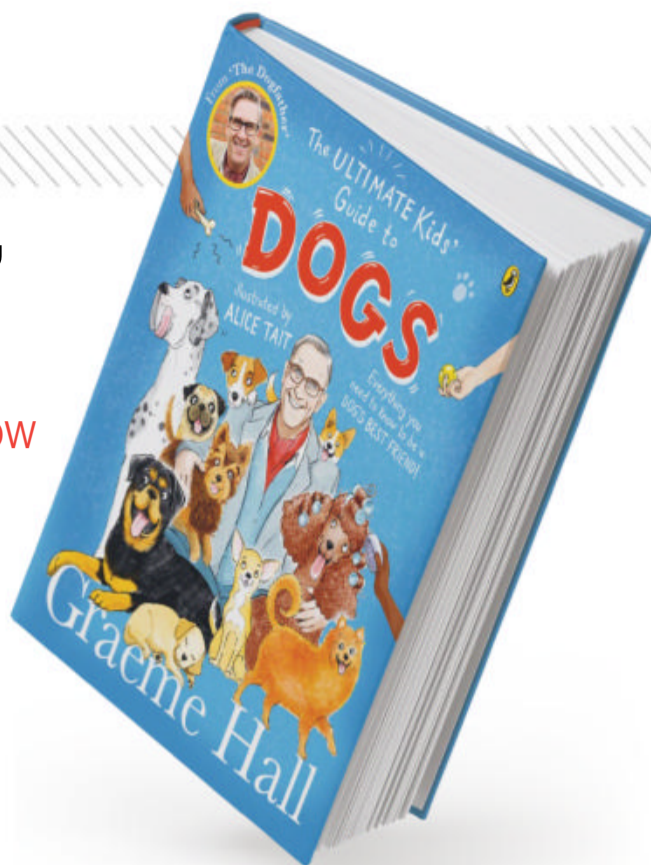
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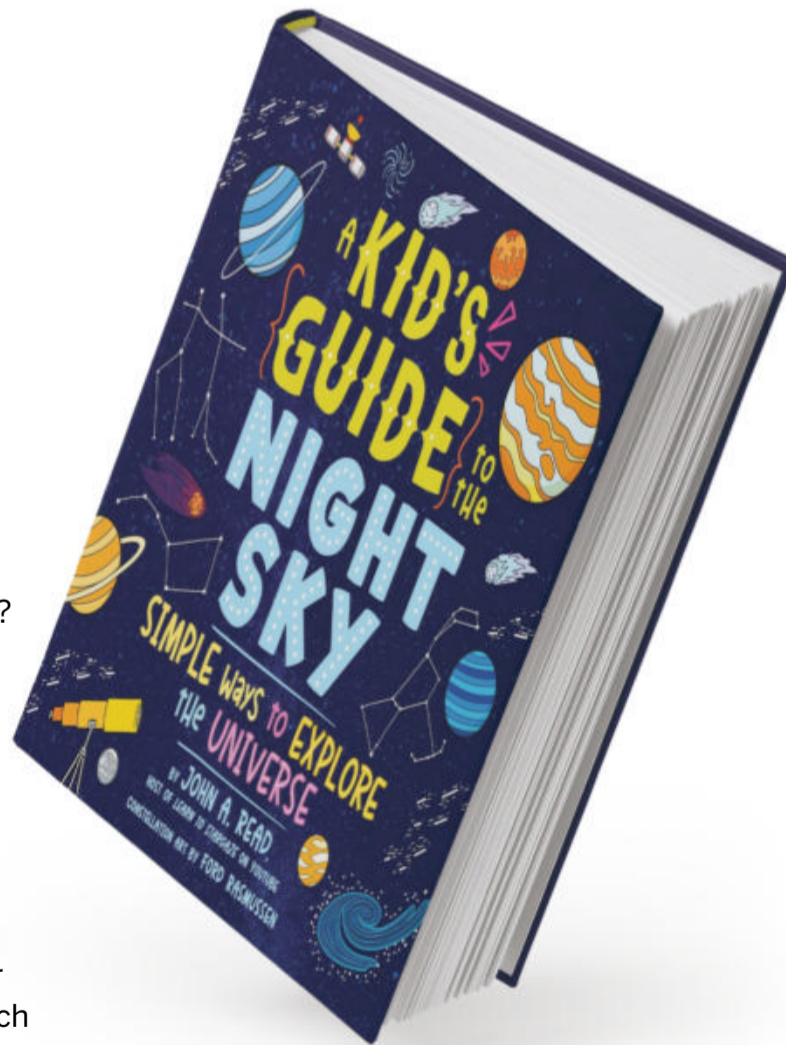
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WHAT IF FUNGI WIN?

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AUTHOR ARTURO CASADEVALL
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Arturo Casadevall is a professor of molecular microbiology and immunology at the Johns Hopkins School of Medicine and the author of *What If Fungi Win?* It's an insightful look at how fungi facilitated evolution and benefited the global biome, but also how they could be the downfall of civilisation. Drawing from research and experience, Casadevall describes the fascinating biology behind fungi, including their amazing powers of radiation resistance and healing abilities. There's an important cautionary tale in *What If Fungi Win?*, too: Casadevall shares the importance of tackling infectious fungi and warns about the rise of drug-resistant species. By the time you've finished this fascinating and eye-opening book, you'll surely have gained a new appreciation for fungi, along with a cautious mindset.



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Sudoku

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	5	2				6		7
3	9			4		8	2	
	7	6		5	2	1		9
2	4					5	8	
			4	8	5	7		2
1			2			9		
					8		5	6
	2		3			4	9	1
9		3	5	1			7	

MEDIUM

	9			7				
5		7				3	9	
				2	9	4	7	
4	8	5						9
3		9		4	5		2	
	2						5	4
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	5							

HARD

				5		2		3
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		2		1				
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4	3	5						8
			9	8				5



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VEGETABLE

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MICROBE
SUPERBUG
MILKING

BIKE
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F	E	B	O	R	C	I	M	W	S	M	I	E	X	E
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C	Y	T	O	G	E	N	I	F	N	R	U	I	P	E
B	K	I	E	Q	M	I	A	R	N	I	P	O	M	T
S	E	A	K	H	O	I	R	E	S	U	A	P	E	A
F	R	U	I	T	B	U	L	G	J	T	O	R	M	B
Y	P	O	B	R	I	E	M	K	U	S	O	K	B	L
G	O	I	T	A	H	S	F	N	I	K	Z	O	T	E
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N	P	K	J	T	H	O	N	C	I	I	G	A	D	J
S	E	W	I	L	K	H	I	N	G	S	E	C	A	H
R	I	S	Z	O	R	A	I	N	C	A	N	L	O	V
T	I	D	S	U	P	E	R	B	U	G	K	O	E	I
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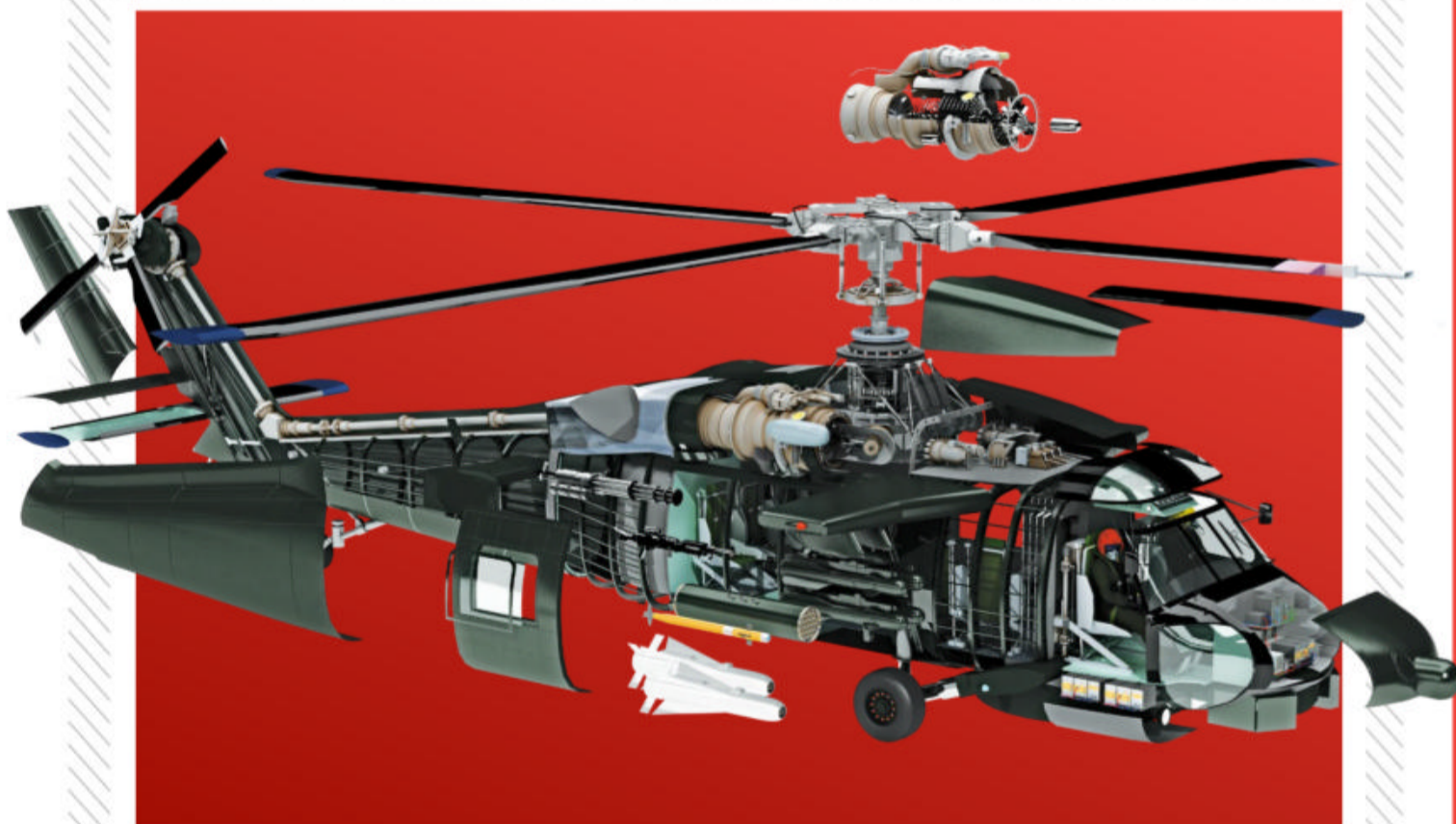
Hint:
Gills, but not for breathing

A



Spot the difference

See if you can find all six changes between the images below



QUICKFIRE QUESTIONS

Q1 Which is not a source of renewable energy?

- Solar
- Wind
- Hydropower
- Natural gas

Q2 Which of these is not a nocturnal bird?

- Owl
- Kiwi
- Nightjar
- Ostrich

Q3 Is light a wave, particle, both or neither?

- Wave
- Particle
- Both
- Neither

Q4 In computing, what does the acronym OS stand for?

- Ordinance Survey
- Original Style
- Oscillating Saw
- Operating System

Q5 Roughly how old is the Solar System?

- 5 million years
- 50 million years
- 500 million years
- 5 billion years

Q6 Which gland in the body produces hormones that control other glands?

- Pituitary
- Pancreas
- Thyroid
- Adrenal

Answers

Find the solutions to last issue's puzzle pages

- Q1** HELICOPTER
- Q2** 20 YEARS
- Q3** CONDENSATION
- Q4** CONCORDE
- Q5** LUCY
- Q6** TROPOSPHERE



What is it?
MATCH

Spot the difference



HOW TO...

Practical projects to try at home

MAKE A STAINED-GLASS ORNAMENT

Create detailed artwork at home in this colourful chemistry experiment



1 GATHER YOUR MATERIALS

The plate or dish will be used to set your glue in. A shallow dish works best, such as the lid of a cylindrical crisp can for a small stained-glass ornament.



2 MIX THE GLUE

Put a couple of tablespoons of glue into one of the plastic cups with an equal volume of water. Mix this together well.



3 FILL THE DISH

Pour the glue mixture into the dish or tray of your choice until it is filled to the edge and has a depth of a few millimetres.



4 A SPLASH OF COLOUR

Disperse around four to five drops of food colouring, dotted across the glue. Don't mix these in.



5 DIP THE DETERGENT

Take a toothpick and dip the end into the washing-up liquid. Place this toothpick in the centre of one of the food colouring drops.



6 PERFECT YOUR PATTERN

Watch as the soap causes the colouring to disperse throughout the glue. Place some soap onto every drop of food colouring to decorate the entire surface.

KIT LIST

- PVA glue
- A plate or dish
- Food colouring
- Washing-up liquid
- Cotton bud or toothpick
- Two small cups

DON'T DO IT ALONE!

If you're under 16, make sure you have an adult with you



7 LEAVE TO DRY

When you are happy with your design, leave the dish flat so that the glue can dry. This will take at least one night.



8 RELEASE THE GLUE

When it's fully dried, it will look clear. Peel the glue out of the dish and hold the ornament against the light to observe the full detail of your design.

SUMMARY

This experiment shows the reaction between the glue-water mixture and washing-up liquid due to surface tension. There is a skin-like structure to the top of the glue as the water molecules are attracted to each other, holding the glue-mixture together. When the washing-up liquid is added, it disrupts this structure because the soap is a surfactant. This means it has molecules with a water-repelling (hydrophobic) end and a water-attracting (hydrophilic) end. When in contact with the water, the surfactant moves quickly, spreading out across the surface. As it does this, it carries the food colouring with it to make dramatic patterns. The polyvinyl acetate (PVA) glue is made of polymer chains. When this dries, it creates a smooth film that doesn't absorb much visible light. This gives the clear stained-glass effect and makes the colours in the pattern much more prominent.

**Had a go?
 Let us know!**

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

DISCLAIMER

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INBOX

Speak your mind

SEND YOUR QUESTIONS OR COMMENTS TO: f HOW IT WORKS MAGAZINE @HOWITWORKSMAG @HOWITWORKSMAG @HOWITWORKS@FUTURENET.COM @HOWITWORKSMAG

SPARKLING STARS

Dear HIW,
I live quite remotely, so always look at the stars at night. Can you tell me why some always seem to twinkle more than others?

Ashley Martinez

A star-embellished sky is one of the most beautiful sights on a clear night. Most stars shine with a steady light, so it seems strange that they glisten with so much regularity. The cause of this movement is actually air, not the star itself. As the light shines through Earth's turbulent atmosphere, some of the light bends away from our eyeline. When you look at the light from a twinkling star, the light is reaching Earth at slightly different angles to give this illusion. Usually, stars closer to the horizon will twinkle more, as there is more atmosphere between you and it.

When the stars near the horizon lose their visibility, it's called atmospheric extinction



You should avoid eating a few hours before exercise to prevent a stitch

WIN!
AN AMAZING PRIZE FOR LETTER OF THE MONTH
DOODLE WITH DUDDLE: HOW TO DRAW DINOSAURS
Learn how to draw your favourite real-life dinosaurs and get ready for an epic dinosaur-drawing adventure

STITCH SCIENCE

Dear HIW,
When I go running soon after eating or drinking I sometimes get a stitch. But I don't know the science behind this. What causes this and what actually is a stitch?

Ava Wright

A stitch can be extremely uncomfortable when running and can make you want to stop instantly. It feels like a sharp pain in your side, or an aching or pulling sensation. As you mention, eating or drinking too soon before a workout may cause this feeling. The jabbing pain can be a result of a spasm in the diaphragm or from blood being diverted away from the area in pain. As this happens, the diaphragm cramps. If you have just eaten and you have food in your



stomach while exercising, more blood will be pumped to the stomach. This means less blood is at the diaphragm, which causes the cramping.

It is best to wait a couple of hours after eating before going for a run. This gives enough time for the food to be digested. The choice of food and drink also makes a difference. To lower the chances of developing a stitch, avoid products high in concentrated sugar before exercising, such as fruit juices. Keeping your posture straight and warming up properly before launching into a run will also reduce the chances of cramping. However, if you get caught in this painful scenario again, slow down and take some deep breaths. Massaging or pressing down on the stitch area can help soothe the pain.

COLD JOINTS

Dear HIW,
I've always wondered, why do my joints hurt more when it's cold?

Sarah Anderson

The joints become stiffer and more sore in cold conditions due to the effect temperature has on blood vessels and nerves. When you get cold, the nerves and blood vessels in the arms and legs constrict, meaning they narrow. This is a useful response by the body, reducing blood flow in limbs and increasing the blood flow circling the core and essential organs. The negative impact of this is that it makes joints move with more difficulty and increases the pain felt.

Another factor thought to contribute to sore joints in the cold is down to changes in synovial fluid. This fluid acts like a lubricant for the joints, but when it gets cold, the fluid thickens. Joint



Heat pads are applied to joints to reduce pain

tissue rubs more when the synovial fluid is thicker, causing pain. By staying active, dressing in warmer clothes and applying heat directly to your joints, you can move more freely.



The strongest tides occur during full Moon

CHANGING TIDES

Dear HIW,

When the tide is out in one place, is the tide in on the other side of the sea?

James Thomas

The tide being out on one side doesn't necessarily mean it's in on the other. Tides are caused by the gravitational pull of the Moon and impacted by the rotation of the planet. The sea rises in a bulge on one side of Earth, where the sea is closest to the Moon. Centrifugal forces also cause a bulge on the opposite side of the planet. At these locations, it's high tide. As Earth rotates, different parts are closest to the Moon. Coastal areas experience two high and two low tides in one day. Because the bulges are on both sides of the planet, the volume of water is more balanced and doesn't shift from side to side with the changing tides.

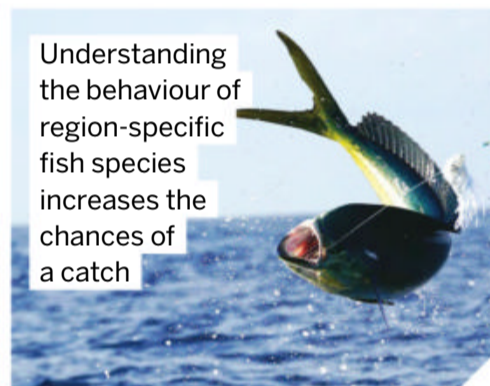
SECURING A CATCH

Dear HIW,

When are fish most active?

Brian Allen

Generally, fish are most active at sunrise and sunset, as the low lighting creates the perfect hunting conditions for them. However, some of the factors that influence the most successful fishing times include the weather, tides and currents and light levels. Many fish tend to be most active during changing tides, when moving water stirs up more food. The weather will also impact the water temperature, altering which fish species are most likely to be active.



Understanding the behaviour of region-specific fish species increases the chances of a catch



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WE ASKED YOU

This month on social media, we asked you:
What do you consider most when buying new clothes?

EMMA DAVIS

THE QUALITY OF FABRIC AND COMFORT OF MATERIAL

ETHAN TAYLOR

CLOTHES THAT STAND OUT. I WEAR LOTS OF BRIGHT COLOURS

OLIVIA B

THE LATEST TRENDS OR ITEMS I NEED

ISABELLE WILSON

I TRY TO GO SECOND-HAND SHOPPING AS MUCH AS POSSIBLE

JAMES LEE

I ALWAYS CHOOSE BRANDS I KNOW AND TRUST

@CAROLJSHELDON

COLOUR

@ALXSPYRIADIS

MATERIALS

NEXT ISSUE

ISSUE 194 ON SALE 5 SEP 2024

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FAST FACTS

Amazing trivia that will blow your mind

**KOALAS
HUG TREES
TO COOL
THEMSELVES
DOWN**



**ONE
GRAM**

The element astatine is so rare, only a tiny amount occurs in Earth's crust

Most elephants weigh less than a blue whale's tongue

**2,700
KILOGRAMS**



20%

One in five stars in the Milky Way has a rocky planet orbiting it

**SOMETIMES
YOUR BRAIN IS
MORE ACTIVE
ASLEEP THAN
WHEN YOU'RE
AWAKE**

67

Several dozen species of bacteria live in your belly button

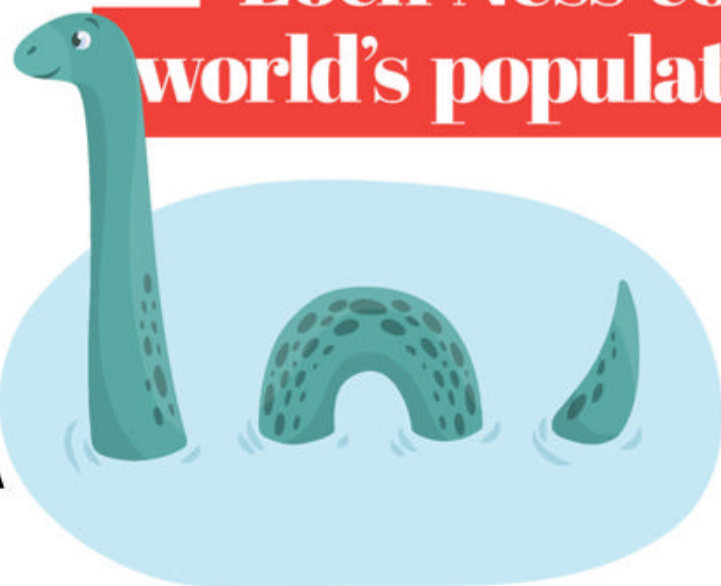
**129
BILLION
TONNES**

There's a huge amount of water in the clouds at any given time



SIX

Paper can be recycled a limited number of times



Loch Ness could contain the world's population ten times over

**15 MILLION
DEGREES
CELSIUS**

The Sun's core is so hot, a pinhead of it could burn you to a crisp from 100 miles away



IF I HAD SOMEWHERE TO LIVE...

I COULD GO ANYWHERE IN LIFE



When Abi's mum died, life got tough. She didn't get on with her dad and the arguments became violent. Abi felt her only choice was to leave home. With just the clothes on her back, and no idea where to go, she ended up sleeping on the streets in the freezing cold.

Right now, you could give a homeless young person like Abi somewhere to start their future

Abi's life changed when she was given a room at Centrepont. A safe place to sleep and recover. A place to develop the skills and confidence she needed to rebuild her life – and leave homelessness behind for good. Now, Abi believes she can go anywhere.

Thousands of homeless young people like Abi are desperately trying to find their place in the world – but first they need a place to start again. **You could help right now by sponsoring a room at Centrepont for just 40p a day.**

We know this support changes lives. 88% of the young people we help move on positively in life. So please, help someone like Abi today. **Thank you.**

Text PLACE to 78866 to donate £3

Call free on 0800 472 5798

Visit centrepont.org.uk/place

Or complete and return the form below



SPONSOR A ROOM. HELP A HOMELESS YOUNG PERSON FIND THEIR PLACE.

YES, I WANT TO SPONSOR A ROOM FOR £12 A MONTH

Please collect my payment on the 1st/15th of every month (please circle preferred date).

Instruction to your Bank or Building Society to pay by Direct Debit

To the Manager: _____
Name and full address of your Bank or Building Society: _____
Originators Identification No.

Postcode _____

Name(s) of Account Holder(s) _____

Bank Sort Code: - - Account Number:

Instructions to your Bank or Building Society: Please pay Centrepont Direct Debits from the account detailed in this instruction, subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with Centrepont and, if so, details will be passed electronically to my Bank/Building Society.

Signature(s) _____ Date _____

Banks and Building Societies may not accept Direct Debit Instructions for some types of account.

Increase your donation by 25p for every £1 you donate with Gift Aid *giftaidit*

By ticking this box I confirm I am a UK taxpayer and want Centrepont to Gift Aid all donations I've made in the last four years and any donations I make in the future until I notify you otherwise. I understand that if I pay less Income Tax and/or Capital Gains Tax in any tax year than the amount of Gift Aid claimed on all my donations it is my responsibility to pay any difference.

Your name and address are needed to identify you as a current UK taxpayer.

Full Name: _____

Address: _____

Postcode: _____ Telephone: _____

Email: _____

Thank you for donating to Centrepont today.

We'd love to show the impact of your support and share how young people continue to need your help, through newsletters, fundraising appeals and information about events. Please let us know how best to stay in touch with you by adding your details above, and ticking the relevant boxes:

Please contact me by email Please contact me by phone

Last year our supporters helped us change the lives of over 15,000 homeless young people. By letting us know we can count on you, we can continue helping young people with a home and a future.

Your privacy is key.

We promise never to sell or swap your details, and will always keep them secure. You can view our Privacy Notice in full at www.centrepont.org.uk/privacy. You can opt out of post and change how we communicate with you at any time. Please call 0800 232320 and speak to one of our friendly team or email supportercare@centrepont.org to do this and ask us any questions.

Please return this form to: **Freepost Plus RTXY-LBEA-UTJJ, Angel Fulfilment Services Ltd, Communication Centre, Par Moor Road, Par PL24 2SQ.**

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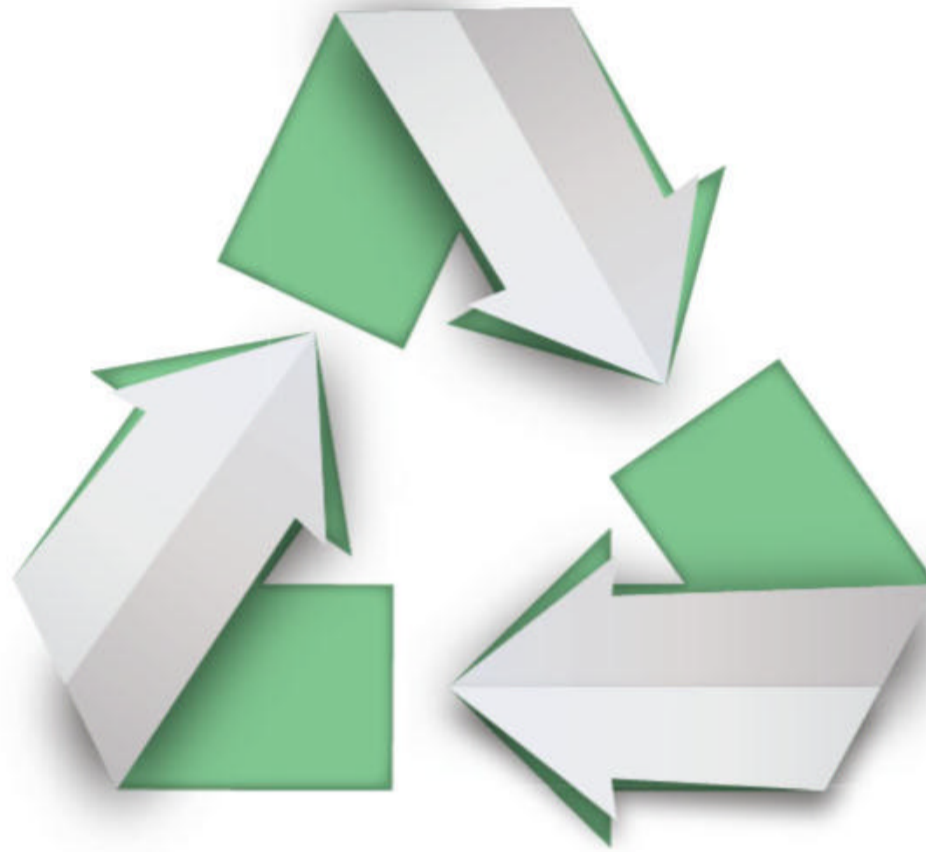
NAP2021CN

Your donation will go towards funding Centrepont's vital work with young people all year round providing accommodation and support. We sometimes use models and change the names of the young people we work with to protect their identity; however all stories are true and as told by the young person.



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